Hydrodynamic Modeling for Tanjung Kepah, Perak

by

Tong Wen Jie

A Project Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

DECEMBER 2006

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
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Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

(Mr Teh Hee Min)

UNIVERSITI TEKNOLOGI PETRONAS

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

TONG WEN JIE

ABSTRACT

The objective of this report is to detail the progress of the computer simulation of coastal hydrodynamic, which is MIKE 21. Firstly, a study has been carried out at Tanjung Kepah, Lumut to study the impacts of wave distribution patterns in that area. Tanjung Kepah is chosen because there are erosion activities going on at the coast. Tanjung Kepah is studied and modeled with the MIKE 21 software to provide the best solution to prevent the erosion acivities. The primary data and secondary data on oceanographical condition, site topography and bathymetry are collected from various sources. Thus, the existing hydraulic environment conditions are analyzed based on the parameters relating to currents, tides, waves and wind. And also, the wave data analysis is carried out to predict the extreme wave heights in various return periods. The execution of computer modeling will cover several phases, which are bathymetry modeling, simulation of wave analysis, and simulation of coastal hydrodynamic incorporated with wave radiation stress. The simulation has been successfully completed, the results are interpreted and analyzed. From the analysis, the incoming waves at a distance of 100 meter from the Tanjung Kepah coast have a maximum wave height of 0.70 meter above ACD during spring high tide at return period of 50 years. The incoming current flow is 0.22 m/s at 320° during flood tide and outgoing current flow is 0.27 m/s at 138° during ebb tide. Thus, this report can be used by the authorities as a reference in order to study the existing coastal hydrodynamic of Tanjung Kepah and decide the preventive actions to be taken to protect the coast. Besides that, the authorities can use this report to do a preliminary design of protective structure, such as breakwaters.

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This project would never have been possible without the contribution of some very special people. I would like to thank them from the bottom of my heart.

To Mr Teh Hee Min, my supervisor. For his constant guidance in every step of this project. And also for his wisdom and constant encouragement, which particularly helped me through all the rough times in this project.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Tanjung Kepah is chosen to be the study area for this numerical modeling project. Tanjung Kepah is situated along the Lumut coastal area and it is accessible by vehicles. It needs 30 minutes drive from Manjung Town to get to Tanjung Kepah coastal area. This location is a problematic site and it is proposed by the authority officer, Hj. Ahmad Zamzuri from Department of Irrigation and Drainage Malaysia (DID), Manjung. According to the officer, the villagers of Kampung Tanjung Kepah had filed a report to the Department of Irrigation and Drainage Malaysia (DID), Manjung because there is critical erosion to the beach shoreline. The villagers are worried about this erosion as they realized that the beach shoreline is receding as time passes.

The local DID officers have responded to this report immediately and investigated the problem faced by the villagers. From the investigation, the officers have identified this problem as category 3 erosion, which is the lowest critical level. This is because the erosion damages the beach shoreline heavily but the hinterland is safe from the destructive waves. After that, the local DID authority installed a protective hard structures, which are gabions along the eroded beach shoreline of the Tanjung Kepah coast. Gabions are big boulders stack on top of each other to form a kilometer of sea walls. This structure has been there for two years.

1.2 Problem Statement

The local authority has no detailed information regarding the Tanjung Kepah site as no hydraulic study has been conducted before. This is because they don't have the required equipments to conduct any hydraulic study in depth at the site. The equipments are tidal gauge, current meter, and etc. Therefore, they have difficulty in understanding the behavior of the site due to lack of resources. Consequently, erosion has occurred to the beach shoreline of Tanjung Kepah as there is no monitoring activity has been conducted at the site. Hence, the authority has suggested us to conduct a case study on the problematic site, so that this report can be used by the authorities as a reference. With this report, they can decide the preventive measures to be taken to protect the coast.

The physical limitation of laboratory experience can be overcome by computer simulation using a well-accepted coastal engineering software, which is MIKE 21. MIKE 21 is a professional engineering software package for the simulation of flows, water quality, waves and sediment transports in the coastal seas. It is also a user-friendly, fully dynamic, 2D modeling system for the detailed analysis, design, management and operation of both simple and complex coastal sea systems. With its exceptional flexibility, speed and use friendly environment, MIKE 21 provides a complete and effective design environment for engineering coastal management, water quality and planning applications.

In conclusions, MIKE 21 is a useful engineering tool to simulate the wave distribution patterns and coastal hydrodynamics with different types of scenarios that cannot be done through physical laboratory experiment.

1.3 Objectives of the Study

For this project, the objectives of the study are as follows:

- To gather information on the environmental forces of the study area through site investigation and data collected from the local authorities.

- To study and interpret the collected raw data through proper analytical methods.

- To computer simulate the coastal hydrodynamics of the problematic.

- To study the impacts of wave distribution patterns in the study area in different scenarios via computer modeling exercises.

1.4 Scope of Study

In order to achieve the objectives, this Final Year Research Project will be divided into major elements as follow:

- Literature Review

  This aspect of the project will be done throughout the whole project duration. The MIKE 21 manuals will be frequently referred to as hydrodynamic modeling is the main gist of the whole Final Year Project. Coastal engineering reference books will also be consulted as to gain a better understanding of the coastal hydrodynamics analysis. Besides that, the modeling guidelines for preparation of coastal engineering hydraulic study and impact evaluation, which is provided by the Department of Irrigation and Drainage Malaysia (DID) will be frequently referred. These guidelines are served as a guide for all the users who are carrying out coastal hydraulic studies using numerical models.

- Identification of Study Area

  A problematic site in Perak, which requires certain extend of wave attenuation is to be chosen as the study area. A site visit is carried out to local Department of Irrigation and Drainage Malaysia (DID), Manjung authority to gain a better understanding of the environmental parameters (wave, tide, current) in the study area. The experience gain from this observation will be used to finalize the output generated by the MIKE 21 when modeling the existing hydraulic regime at the study area.

- Meetings with Authorities and Personnel-in-Charge at Site

  The meetings with the authorities and personnel-in-charge at the site are important in order to obtain all the relevant oceanographic and meteorological data as well as site bathymetry within the study area.

- Collection of Primary and Secondary data

  The collection of primary data is important as this data will be used to set up the modeling of the existing hydrodynamics regime of the problematic site. The primary data are stated below:

  - Meteorological data is obtained from *Perkhidmatan Kajicuaca Malaysia*. The data include monthly maximum surface wind, annually wind rose, monthly wind rose and percentage frequency of various directions and speeds. These data are observed at Sitiawan meteorological observation station and taken from 1968 to 2005.
  - Oceanographic data (Marsden Square of 2630, 2640, 2650, 2739, and 2759) is obtained from Department of Irrigation and Drainage, Malaysia. The data include the maximum wave heights for 0° to 360°, wave rose for annual statistics and wave rose for South East Monsoon. These data are taken from 1948 to 1984. The Marsden Square of a chosen location can be referred to **Appendix 1-1**.
  - Field data collection from the proposed Environmental Investigation Assessment report for Marina Island Project at Teluk Muroh. The data include observed and simulated current speeds and directions.

- Tide Levels from the 2006 Tide Tables for Malaysia published by the Hydrography Department of the Royal Malaysian Navy. The data is extracted at Lumut, Perak Darul Ridzuan on the month of March and April.

The secondary data is bathymetry chart. This bed bathymetry will be used in the MIKE 21 simulation works was extracted from the following chart or drawings:

- Admiralty Chart No. MAL 554 (Peninsular West Coast)
  Pulau Pinang – Kepulauan Sembilan   Scale 1:200 000 (Lat 4° N)
  Published by Royal Malaysian Navy (15th July 2003)

- <u>Desk Study of the Collected Information</u>

  After obtaining the primary data from various sources, this primary data are considered raw. This data needs to be processed before they can be implemented into the MIKE 21 modeling software. Desk study is required to understand the collected primary data and calculations are done on these data.

- <u>Wave Analysis</u>

  Analysis will be done on the wave primary data in order to determine the extreme wave height, maximum wave height, and wave transformation, such as wave reflection and wave refraction.

- <u>Software Application</u>

  The application of MIKE 21 modeling software is used to investigate the wave distribution pattern of the following scenario:

  - Investigate the dominant wave force and direction with different period of time intervals, such as 2 years, 5 years, 10 years, 20 years, 50 years and 100 years.

- <u>Assessment of the Numerical Results</u>

  The MIKE 21 modeling software will generate results and figures of the wave distributing patterns and coastal hydrodynamics after all the primary data are input into modeling software. With these results and figures, the existing hydraulic environment condition based on parameters relating to currents, tides, waves, and wind can be analyzed and justified.

- <u>Comment and Conclusion</u>

  From the assessment of the numerical results, the impact of the wave activities can be justified in order to further study the existing coastal hydrodynamic in Tanjung Kepah and provide relevant information that can be used as a reference to design a preliminary preventive measures at Tanjung Kepah.

- <u>Thesis writing</u>

  All the data and results of this project will be compiled as a thesis writing for the Final Year Project I & II. This thesis will be used as a reference for any projects that will involve the selected problematic site.

CHAPTER 2

LITERATURE REVIEW

2.1 Wave Transformations

Processes that can affect wave as it moves from deep to shallow water include shoaling, breaking, refraction, diffraction, reflection and wave run-up. Thus, the will be focused on wave shoaling such as wave shoaling, wave refraction, wave reflection and wave breaking.

2.1.1 Wave Shoaling

As the deepwater wave begins to enter more shallow water (i.e. $d < 0.5\ L$), it begins to 'feel bottom'. Thus, wave is transformed. The waves are slowed, shortened, and steepened, as they travel from deeper water into more shallow water. The wave shoaling is illustrated in **Figure 2.1 and Figure 2.2**.

Simple shoaling is defined as change in wave energy due to the action of physical processes. Height, H and length, L may change, however the wave fronts remain parallel to the bottom contours. Hence, time, T remains constant as the wave propagates.

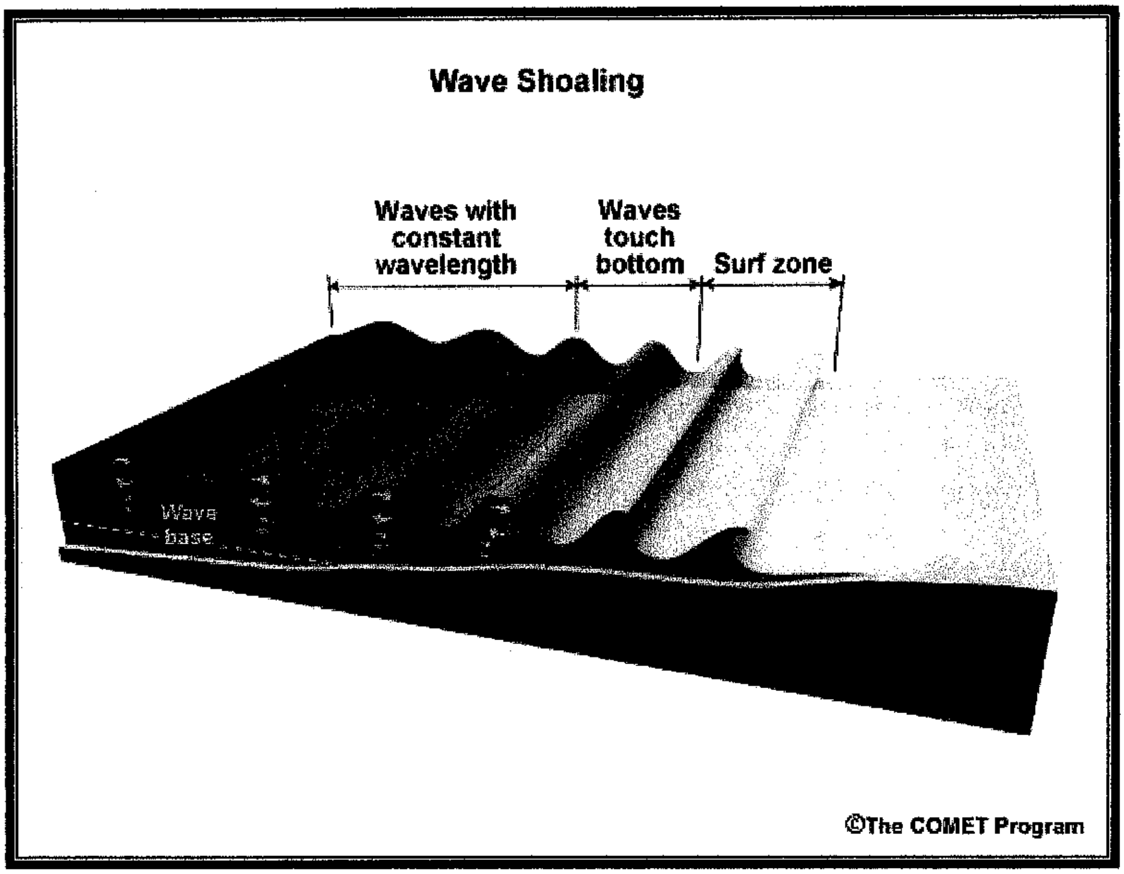


Figure 2.1: Wave shoaling

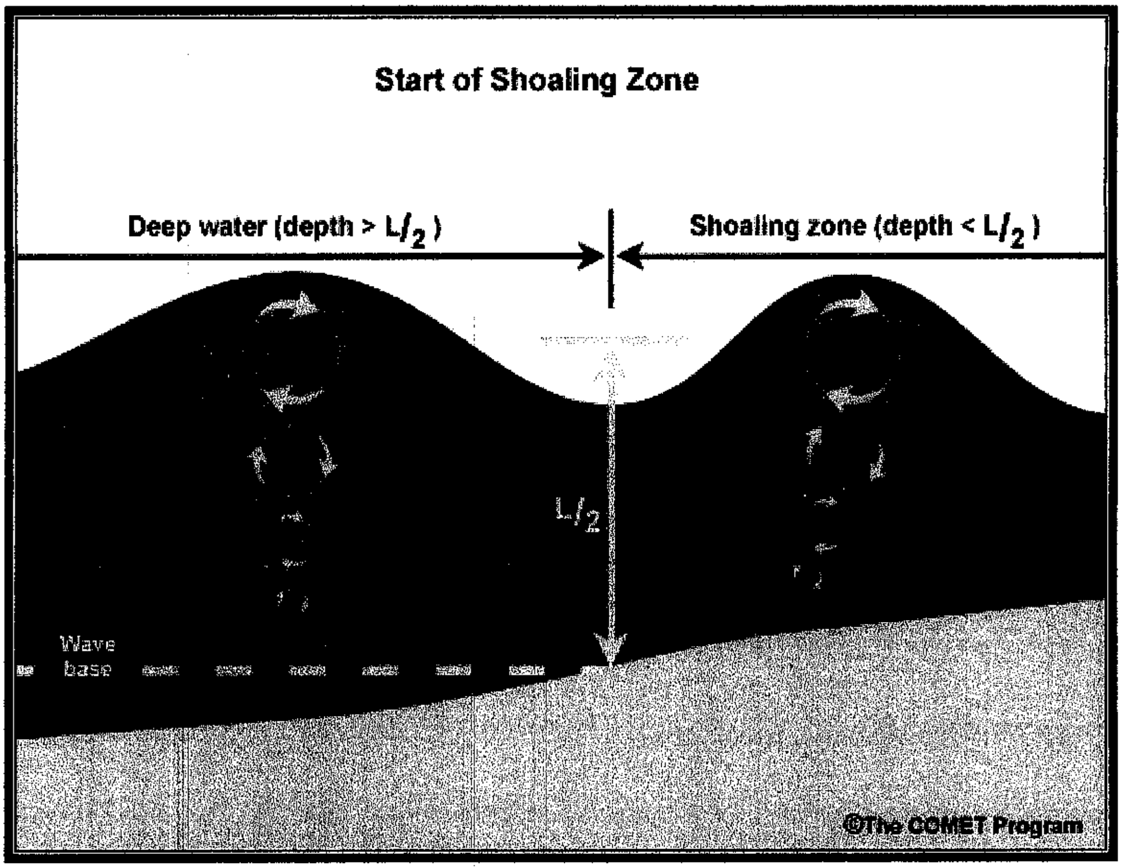


Figure 2.2: Close up of wave profile

Shoaling effect occurs when the presence of the seabed or beach affect the celerity of the wave energy. This effect may be applied to stretch or concentrate the energy, so it may increase or decrease the wave amplitude.

The change in wave amplitude is measured by the shoaling factor, K_s

$$K_s = \frac{H}{H_o'} \tag{2.1}$$

2.1.2 Wave Refraction

When waves approach the shore at an angle, wave refraction takes place in addition to wave shoaling. During refraction, the wave crests bend to align themselves with the bottom contours and the wave direction becomes more perpendicular to the shore. The wave refraction can be illustrated in **Figure 2.3.**

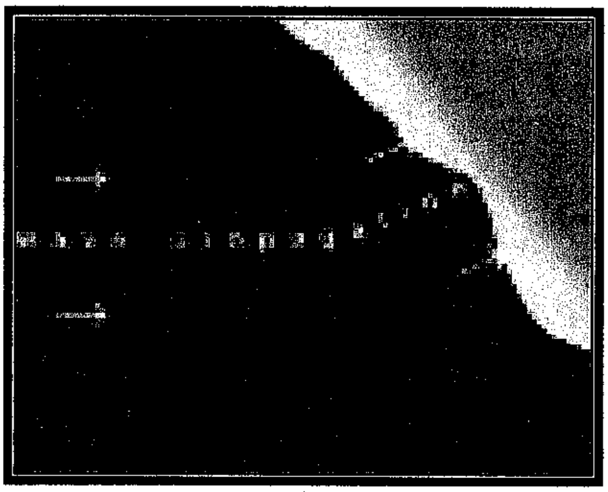


Figure 2.3: Refraction of a straight wave crest

Wave refraction is the bending effect of wave crest in order to align with bottom contours or bathymetry, as waves are moving over different depths. Refraction is a con sequence of the dependence of the wave celerity upon the water depth and start as soon as the wave begins to feel the seabed.

Transitional water:

$$C = \frac{gT}{2\pi} tanh(\frac{2\pi\pi}{L}) \qquad (2.2)$$

Shallow water:

$$C = \sqrt{gd} \qquad (2.3)$$

Equation (2.2) and (2.3) show that C depends on d and C in deepwater is independent of d.

Wave refraction occurs most significantly in transitional and shallow water. Waves converge or diverge due to the shape of the bottom topography which influences the direction of wave travel as show in **Figure 2.4**. This causes wave energy to be concentrated or spread out. For example, waves diverge due to the submarine canyon and waves converge due to the submarine ridge. Waves will also converge where there are points or promontories projecting into the sea, such as headlands, wave fronts on both sides turn toward the point. A greatly increased amount of wave energy will be focused toward the point, and will tend to wear it away over time.

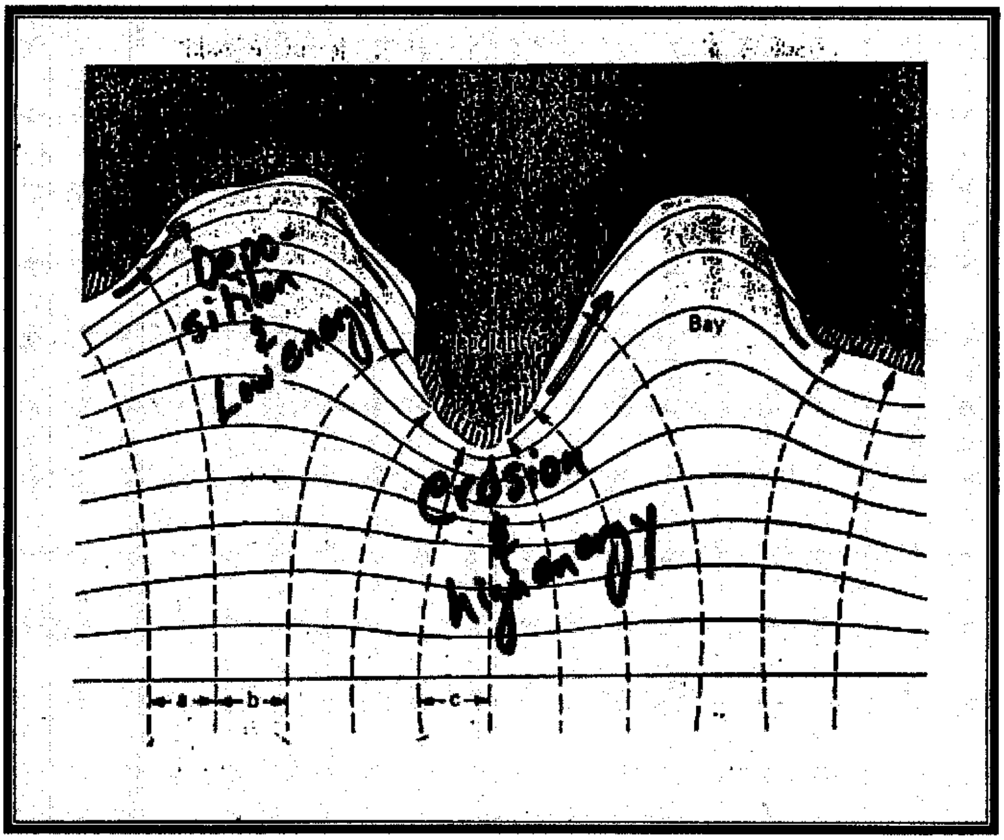


Figure 2.4: Converging and diverging orthogonal energy

The wave characteristic such as wave height will change if wave enters a shallow area under an angle. Wave refraction analysis provides nearshore transformation of waves from deepwater condition to shallow water. The analysis also determines the shallow water wave height and distribution of wave energy along the coast, which results in convergence or divergence pf wave energy and also determines erosion and deposition of beach materials.

Refracted wave height, H_i is given by:

$$Hi = Ho \bullet Ks \bullet Kr \tag{2.4}$$

where, H_o = Deepwater wave height

K_s = Shoaling coefficient

K_r = Refraction coefficient, $K_r = \sqrt{\frac{B_o}{B}} = \sqrt{\frac{\cos\alpha_o}{\cos\alpha}}$

Snell's law of wave refraction can be used to calculate wave angles as

$$\frac{\sin\alpha}{\sin\alpha_o} = \frac{C}{C_o} = \tanh\frac{2\pi d}{L} \tag{2.5}$$

2.1.3 Wave Reflection

Wave reflection occurs when wave energy is reflected as the waves hit into a rigid obstruction such as breakwater, seawall, cliff, etc. this is especially obvious where the surface is a smooth vertical wall.

Degree of wave reflection is defined by the reflection coefficient, C_R, expressed as

$$C_R = \frac{H_r}{H_i} \tag{2.6}$$

where H_r = reflected wave height

H_i = incident wave height

The amount of reflected wave depends very much on the type of obstacle that it comes across. Factors, such as permeability, angle of approaching wave, surface roughness and surface slope, are the governing parameters to wave reflection. For example, the reflection coefficient for a wave that approaches a rigid impermeable vertical wall is one ($C_R = 1$). This shows that the wave is fully reflected. As for a permeable or porous structure that has a surface slope, the reflection coefficient will have a value between zero to one ($0 < C_R < 1$) whereby, this is known as partial reflection. And, for near-shore wave propagation problems, the reflection coefficient is zero ($C_R = 0$) because wave energy is often less than 10% of the incident wave.

2.1.3 Wave Breaking

Wave breaking happens when there is reduction in wave energy and height in the surf zone due to limited water depth. Wave breaking is dominant in the surf zone, where the region extends from the seaward boundary of wave breaking to the limit of wave uprush. There are two types of breaking waves, which are open-water whitecaps (happens in deepwater) and near-shore breaker (shallow/transitional water).

Open-water whitecaps can only be produced by high winds. Wind increases the wave height at a faster rate than the wavelength can increase. As wave gets too tall to support itself, the wave breaks. Or when the ratio of wave height to wave length is more that 1/7, the wave breaks. Increasing height or decreasing the wave length will cause a whitecap.

Near-shore waves will break when the waves feel the bottom of the bed. The cycloid motion reaches to the bottom and becomes disorganized. Thus, the cycloid motion will disturb, erode and transport the sediments. Underwater friction and turbulence at the bottom slows the wave and shortens the wavelength. The wave will become steeper as the wave height is increased. There are three breaker types, which are spilling breaker, plunging breaker and surging breaker.

Spilling breaker occurs at the very flat nearly horizontal beach and happens at any time. These waves break far from the shore, and the surf gently rolls over the front of t he wave. The water at the crest of a wave may create foam as it spills down the face of the wave. This is the wave most swimmers are used to. Once in a while, this wave will create a tunnel effect so called a "Tube" of "Pipe" buy surfers.

Plunging breaker occurs at the moderate steep beach and happens only at high tide period. This type of wave is the most violent and dangerous wave. However, expect surfers love this type of wave. The wave curls over forming a tunnel until the wave breaks and plunges down the face of the wave in a violent tumbling action. Resulting in high splash and scour into sea bottom. Plunging breakers are more commonly associated with swell waves that approach the beach with much longer wavelengths.

Surging breaker occurs at the very steep beach, rocky shorelines, jetty or man-made seawall. Wave crest remains unbroken and the front face of the wave advances up the steep beach with minor breaking. The entire face of the wave usually displays churning water and produces foam, but an actual curl never develops. This type of breaker is often described as creating the appreance that the water level at the beach is suddenly rising and falling. These kinds of breakers are known for their destructive1 nature.

2.2 Long-Term Wave Analysis

The analysis of long-term wave data provides a theoretical distribution of probability of occurrence of wave parameters over several years. Such analysis is most commonly carried out on long-term wave height data; a series of observed or hindcast wave heights spanning years or decades. Each wave height in the data series summarizes a short-term wave condition and thus, represents waves existing over several hours. Normally, the parameter used to summarize the short-term wave height distribution is the significant wave height. Long-term distributions of wave periods and wave angles are usually considered to be a function of the long-term wave height distribution.

Long-term wave height analysis has two specific purposes, which are to organize the wave height data and to extrapolate the data to extreme (high) values of wave heights occurring at low probabilities of exceedence. There are a number of ways in which this can be done. Least squares regression analysis issued, simply because it is the most readily available and most universally understood statistical tool. There are 4 types of distribution in the long-term wave analysis for determining extreme wave height values from grouped data obtained from a complete long-term data set. These 4 distributions are:

- Normal Probability Distribution
- Log-Normal Probability Distribution
- Gumbel Distribution
- Weibull Distribution

According to a reference of Introduction to Coastal Engineering and Management by J. William Kamphuis, it is best to use all the available data in as many ways as possible to gain confidence in the final results, since extrapolation to higher wave heights and longer return periods is a basic and very important part of any design. The Weibull, Gumbel and Log-Normal distributions can be used successfully to organize and extrapolate wave height data. These distributions can be expected to yield good results. However, J. William Kamphius has stated that Gumbel distribution is possible to use distributions developed specifically for analysis of extreme values. These models were originally derived for a limited number of "ordered statistics" such as a set of maximum annual floods arranged in descending order.

2.2.1 Gumbel Distribution

Gumbel distribution is an extreme value distribution because it has two parameters in the distribution.

$$P = exp\left(-exp\left(-\left\{\frac{H-\gamma}{\beta}\right\}\right)\right) \tag{2.7}$$

This may be linearized by taking the logs of both sides

$$ln\,P = -exp\left(-\left\{\frac{H-\gamma}{\beta}\right\}\right) \tag{2.8}$$

and taking logs again

$$-ln(-ln\,P) = \frac{H-\gamma}{\beta} \tag{2.9}$$

or

$$-ln\left(ln\frac{1}{P}\right) = \frac{H-\gamma}{\beta} = \frac{1}{\beta}H - \frac{\gamma}{\beta} \tag{2.10}$$

The reduced variate (Y), we will call G. the resulting transformation is

$$Y = -ln\left(ln\frac{1}{P}\right) = G; \qquad X = H; \qquad A = \frac{1}{\beta}; \qquad B = -\frac{\gamma}{\beta}; \tag{2.11}$$

The parameter γ in the Gumbel distribution has physical meaning. It is a lower limit of H (when $H = \gamma$, $P = 0$). Thus γ is theoretically equal to the threshold value in a Peak over Threshold data set.

2.2.2 Transformation of Coordinate Axes

A probability that any wave height H' is equal to or less than a specified wave height H is defined as

$$P = P(H' \leq H) \tag{2.12}$$

Plotting P against wave height, results in the Cumulative Distribution Function. A Probability of Exceedence that H' is greater than a specified wave height may also be defined as

$$Q = Q(H' > H) = 1 - P \tag{2.13}$$

The results are plotted and it is seen that the resulting Cumulative Distribution Function organizes the long-term wave height data, but it is difficult to extrapolate. Since the most robust relationship for both interpolation and extrapolation is a straight line, a Cumulative Distribution Function needs to be transformed into a straight line by transforming the axes of the graphs. The equation for the transformed linear model will then be

$$Y = AX + B \tag{2.14}$$

Here Y is the transformed probability axis, often called the reduced variate, and X is the transformed wave height axis. The coefficients A and B are the slope and intercept of the straight line relationship and they are determined by linear regression analysis.

2.2.3 Wave Height Predictions for Various Years

The above long-term wave height analysis meets both criteria because it organizes the data and the co-ordinate transformations develop linear relationships that can be interpolated or extrapolated with some confidence to smaller exceedence probabilities. The wave height, H for a return period of T_R years may now be determined. From the data, the number of events per year on which the analysis is based (λ) can be calculated.

$$\lambda = \frac{\sum N_{Events}}{\sum N_{Year}} \tag{2.15}$$

where λ = Total number of events per Total number of years

The exceedence probability of one event in T_R years would be

$$P = \left(1 - \frac{1}{\lambda T_R} \right) \tag{2.16}$$

Therefore, wave height predictions for Gumbel distribution

$$H_{T_R} = \gamma - \beta\, ln\left(ln \frac{1}{P} \right) = \gamma - \beta\, ln\left(ln \left\{ \frac{\lambda T_R}{\lambda T_R - 1} \right\} \right) \tag{2.17}$$

2.3 Numerical Modeling (MIKE 21 2002)

MIKE 21 is a professional engineering software package for the simulation of flows, water quality, waves and sediment transports in the coastal seas. It is also a user-friendly, fully dynamic, 2D modeling system for the detailed analysis, design, management and operation of both simple and complex coastal sea systems. With its exceptional flexibility, speed and use friendly environment, MIKE 21 provides a complete and effective design environment for engineering coastal management, water quality and planning applications. Applications related to the MIKE 21 include:

- Tidal exchange and currents
- Wave disturbance and breakwater alignment
- Morphological modeling
- Offshore waves

MIKE 21 consists of many new modules and new features. Two modules are selected to model the existing environmental conditions of the study area at Tanjung Kepah. The modules are MIKE 21 Flow Model (MIKE 21 FM) and MIKE 21 Nearshore Spectral Wind-wave Module (MIKE 21 NSW).

2.3.1 MIKE 21 Hydrodynamic (MIKE 21 HD)

MIKE 21 Hydrodynamic is a general two-dimensional modeling tool for oceanographic, coastal and estuarine applications. The model comprises a hydrodynamic model. The model can depend on a number of external forcing, as e.g. meteorological effects and boundary conditions, which can be incorporated in a flexible manner. The model is based on an unstructured flexible mesh, which provides an optimal flexibility while retaining an efficient numerical solution. It uses a Finite Element solution technique. The meshes are based on linear triangular elements. Combined with a semi implicit time marching schemes, this gives an efficient solution procedure.

2.3.2 MIKE 21 Nearshore Spectral Wind-wave Module (MIKE 21 NSW)

MIKE 21 NSW is a wind-wave model that describes the propagation, growth and decay of short-period and short-crested waves in near shore areas. The model takes into account the effects of refraction and shoaling due to varying depth, local wind generation and energy dissipation due to bottom friction and wave breaking. The model also takes into account the effect of wave-current interaction.

The basic output from the model is integral wave parameters such as significant wave height, mean wave direction, the directional standard deviation and radiation stresses. In addition, spectral output data in form of distribution of wave energy on directions at a number of user-selected points can also be obtained.

MIKE 21 NSW can be applied to the study of wave disturbance in coastal areas. The assessment of the wave conditions, such as wave heights, wave periods and wave directions, are essential for the estimation of wave forces at a shoreline. The wave-induced currents are generated by the gradients in radiation stresses that occur in the surf zone. MIKE 21 NSW can be used to calculate the wave conditions and associated radiation stresses.

2.4 Guidelines for Preparation of Coastal Engineering Hydraulic Study Using Numerical Methods and Impact Evaluation

2.4.1 Components of a Coastal Hydraulic Model

The coastal hydraulic model consists of a suite of modules, each of which is used to simulate particular coastal processes. The module, which is going to be used in assessing the existing hydraulics regime of a study area, Tanjung Kepah is Nearshore Wave Module. This module is used to transform deep sea waves to the near shore waves considering the various transformation processes such as refraction, shoaling and wave breaking.

2.4.2 Model Set Up

Modeling works are carried out using two levels, which are coarse grid model and fine grid model. The coarse grid model uses a large spacing, 1 km depending on the size of the area to be modeled. The grid spacing in the fine grid model is very important because it determines the accuracy of the output. The fine grid spacing shall generally be less than 50 m.

For the fine grid model the outer boundary of the model shall be sufficiently far away from the study area so that they will not introduce any inaccuracies in the study area. The study area shall generally be at least 50-grid spacing away from the model boundary. Another condition is that the boundary shall not fall on or be adjacent to river mouth areas as this will introduce inaccuracies unless detailed information regarding current and sediment flow from the river is available.

2.4.3 Data Requirements for Various Modules

a) Data for near shore wave module

- The data required for this module are deepwater wave characteristic and the bathymetry of the study area.

b) Data for assessment of river mouth effects

- The data required for this assessment are flow characteristics, river cross sections and tidal characteristics at the river mouth.

2.4.4 Model Calibration

The model calibration is normally carried out by comparing the predicted water levels and current velocities at spring and neap tides with the measured values and making the necessary adjustments to the various model parameters so that these two sets of data match as closely as possible.

2.4.5 Model Verification

The verification of the model is carried out by comparing the predicted water levels and current velocities to actual measured values. The average differences in speed and direction shall not be more than 30% and 45° respectively. The average difference in water level shall not be more than 10%. The general pattern of speed and direction shall be similar. The differences between the predicted and measured values shall be treated as absolute values and these values shall be averaged over the duration of comparison. The time interval between each consecutive value shall be less than 60 minutes.

2.4.6 Simulation of Impacts for Nearshore Wave Module and Presentation of Results

This module transforms the deepwater waves to nearshore waves. The results of the wave transformation module may consist of wave height and direction for the existing hydrodynamic regime of the study area. For these cases, any wave reflection caused by the development may also be included.

During the low tides, the waves may break away from the coastline, while during the high tides; the waves may break closer to the shore. Ideally, this module shall use a varying water level that depends on the tides. However, if this is not possible, then, in order to assess the worst conditions, the mean high water shoreline (MHWS) level shall be used as input for the water level in this module.

The results shall be presented in such a manner so as to facilitate easy inference of the changes in the wave pattern. If the wave pattern is affected by the development works, then it is necessary to provide wave pattern diagrams for the existing hydrodynamic regime of the study area. The diagrams may consist of the following:

- Wave patterns diagrams in plan view for the existing hydrodynamic regime of the study area with difference diagrams.
- Sectional transects showing wave height variation for the existing hydrodynamic regime of the study area.

2.5 Soil Classification

2.5.1 Sieve Analysis

Sieve analysis consists of shaking the oven-dry soil sample through a set of sieves that have progressively smaller openings. This experiment is conducted under U.S. standard sieves numbers and the sizes of openings. After the experiment has being conducted, the mass of soil sample left on each sieve is determined by using the following equation 2.18:

$$\text{Percentage retained on any sieve} = \frac{\text{Mass of soil retained}}{\text{Total soil mass}} \times 100 \qquad (2.18)$$

The results of the sieve analysis method can be plotted in the form of a graph on semi-log paper with the percentage finer on the arithmetic scale and the particle diameter on the log scale. An example of particle size distribution curve semi-log paper is shown in **Appendix 2-1**. These results are determined from the following equations:

$$\begin{aligned}&\text{Cumulative percentage} = \text{Sum of percentages retained on all sieves} \qquad (2.19)\\&\text{retained on any sieve}\end{aligned}$$

$$\begin{aligned}&\text{Percentage finer than any} = 100\% - \text{Cumulative percentage retained} \qquad (2.20)\\&\text{sieve size, } P\end{aligned}$$

2.5.2 Particle Size Distribution Curve

The shapes of the curves that are plotted on the semi-log paper with the percentage finer against particle diameter can be classified into:

- Poorly graded
- Well graded
- Gap graded

Poorly graded soils are represented by nearly vertical lines. This shows that the soils contain particles of almost the same diameter. A well graded soil possesses a wide range of particles sizes ranging from gravel to clay size particles. And a gap graded soil has some of the sizes of particles missing.

To determine the uniformly graded or well graded soil, Hazen (1893) has proposed the following equation:

$$\textit{Uniformity coefficient, } C_u = \frac{D_{60}}{D_{10}} \tag{2.21}$$

where D_{60} = Diameter of the particle at 60 per cent finer on the grain size distribution curve

D_{10} = Effective particle size at 10 per cent finer particles

The distribution of the soil particle can be determined by using uniformity coefficient, C_u:

$C_u > 4$	for well graded gravel
$C_u > 6$	for well graded sand
$C_u < 4$	for poorly graded soil

CHAPTER 3

PROJECT AREA SETTING

3.1 Overview of the Study Area

A problematic site along the Lumut coastal area is needed so that the computer can simulate the existing coastal hydrodynamics of the site by using MIKE 21 modeling software. A meeting took place at the Department of Irrigation and Drainage Malaysia (DID), Manjung between the authority officer, Hj. Ahmad Zamzuri and a group consisting of a Final Year Project student, Tong Wen Jie and 2 lecturers, Mr. Teh Hee Min and Miss Zahiraniza Mustaffa from Universiti Teknologi PETRONAS. The purpose of this meeting is to determine the location of the study area or the problematic site and also to obtain primary data, such as wave, wind, current and tides data from the authority.

Hj. Ahmad Zamzuri had proposed a study area to us, which is at Kampung Tanjung Kepah. Kampung Tanjung Kepah is situated at Tanjung Kepah in Manjung district and it is 30 minutes drive from Manjung town. The villagers of Kampung Tanjung Kepah had filed a report to the Department of Irrigation and Drainage Malaysia (DID), Manjung because there is critical erosion to the beach shoreline. The villagers are very worried about this erosion as they realize that the beach shoreline is receding as time passes. The local DID officers has responded to this report immediately and dispatched a team to investigate the problem faced by the villagers.

The coast of Tanjung Kepah is a muddy coast because Tanjung Kepah is situated slightly north to the river mouth of Perak River. Perak River contributes to the coast of Tanjung Kepah by bringing fine silt and clay to be deposited along the muddy coast. Besides the deposition of fine materials from the river, there are mangrove forest along the coast to be the barrier and protector of the coast against the destructive waves from eroding the beach shoreline.

The investigation team has determined the sources of the problem that cause erosion to the coast. There are some sections of the mangrove forest are being cleared and illegal 'udang harimau' farms are built on these sections. With some parts of the mangrove forest are being cleared, this will cause the cleared area to be exposed to the destructive waves and erosion will occur to the beach shoreline. There is a Tenaga Nasional Berhad energy plant, which is built on a man-made island near Pasir Bagok, Pulau Pangkor. To build this man-made island, it needs a lot of material to fill up to become as island. Therefore, the contractor did a sand mining operation to build this island and this operation needs a huge volume of sand. But, the investigation team found out that the sand mining operation had been carried out at near shore. The operation had left a negative impact to the beaches around the area. As it took a huge amount of sand out from the area, that area is said to be hunger for sand or also known as sand sink. The sand sources will concentrate to this sand sink as to fill up the volume losses back to its normal condition. Thus, there will be no net deposition to the surrounding beaches and the beach shorelines keep eroding. This is greatly felt by the Tanjung Kepah coast. Supposedly, the operation must be done a few kilometers away from the construction site or in deep water region because the propagated wave at the deep water region will not feel the sea bottom.

The investigation team has categorized this problem as erosion at Category 3, which is the lowest critical level. This is because the erosion damages the beach shoreline heavily and the hinterland is safe from the destructive waves. After determined the problem, the local DID authority took an immediate action and implemented a protective hard structures, which are gabions along the eroded beach shoreline of the Tanjung Kepah coast. Gabions are big boulders stack on top of each to form 1 kilometer of sea walls. This structure has been there for two years and the first layer has been top-up with another layer of gabion. This causes the sea wall to be two meters high. The additional layer is added because the area has been affected by minor tsunami waves as the wave run-up to the first layer. This whole operation costs the government to spend RM 800, 000 to put up protective structures along this eroded coast.

The local DID authority officer, Hj. Ahmad Zamzuri has suggested to us to study the area and propose a suitable cost-effective protective structure to improve the current situation at Tanjung Kepah coastal shoreline. After obtaining all the necessary primary and secondary data from the authorities, literature review has been carried out to further my understanding on my modeling research on my study area. The literature review will be focused on wave transformations, long-term wave analysis and guidelines for preparation of coastal engineering hydraulic study using numerical models and impact evaluation published by DID.

3.2 Location of the Study Area

Tanjung Kepah is located at 4° 7' 11.01" North, 100° 44' 18.33" East. It is situated in Lekir district in Mukim Manjung. **Figure 3.1** shows the location of Tanjung Kepah from the satellite view. From this figure, there is a big river channel flowing out towards the open sea. This main river is Perak River and it is located at about 13km from the Tanjung Kepah.

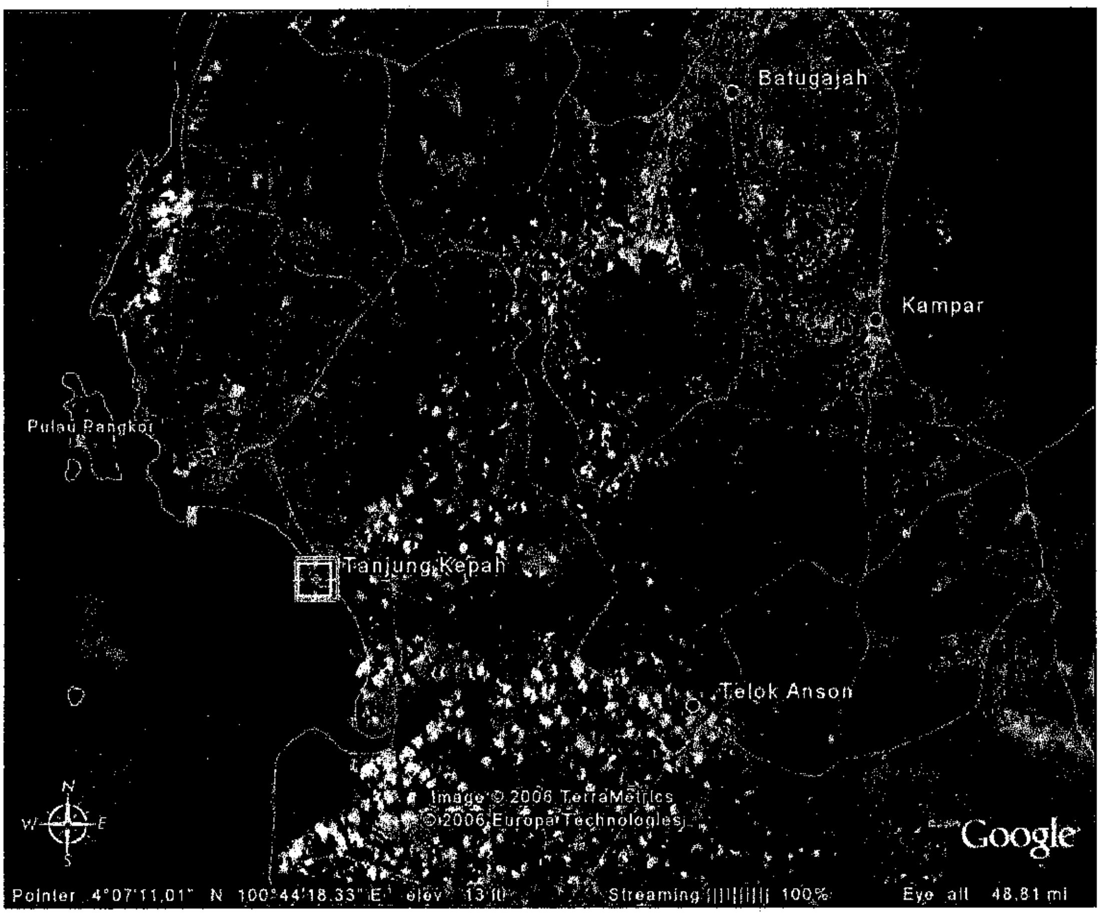


Figure 3.1: Tanjung Kepah satellite image

Note: The cross-hair mark indicates the location of Tanjung Kepah.

3.3 Site Description

Previously, Tanjung Kepah is used to be a mangrove coast, where mangrove grew along the beach. But now, the mangroves are dying due to aggression of sand from Perak River (sedimentation), which situated approximately 9 miles or 15 km from Tanjung Kepah. Mr. Roslan, the representative of DID told that there might be activities such as logging, construction and others that take place at the upstream of Perak River which contribute sediments to the river discharge. There was once a sand mining activity at the nearshore, somewhere near Pulau Pangkor and Tanjung Kepah. This activity is due to the land reclamation project to build a man-made island for Tenaga Nasional Berhad energy plant. This project brought negative impacts to Tanjung Kepah coastal area and the surrounding areas of Lumut coast. The negative impacts are sediments depression along the shores as well as causing changes to shorelines because net erosion is higher than net accretion of sediment transport.

3.3.1 Existing River

Sediments from Perak River are being transported to the sea by the river flow. When the river meets the sea, the nearshore current coincides with the river current, causing the current to have an angle (oblique) when approaching the shore. The front part of the wave touches the shallow nearshore first and slows down. The remaining section of the wave bends as it approaches the nearshore creating the waves to propagate parallel with the beach. Thus, longshore currents also referred to as littoral currents to occur in the nearshore.

Littoral drift is the movement of sediments along the coast in a preferred direction that is typically in response to a predominant wind direction. By littoral drift, the sediments from upstream of Perak River are being transported along Tanjung Kepah beach. **Figure 3.2** shows the littoral drift along the Tanjung Kepah coast.

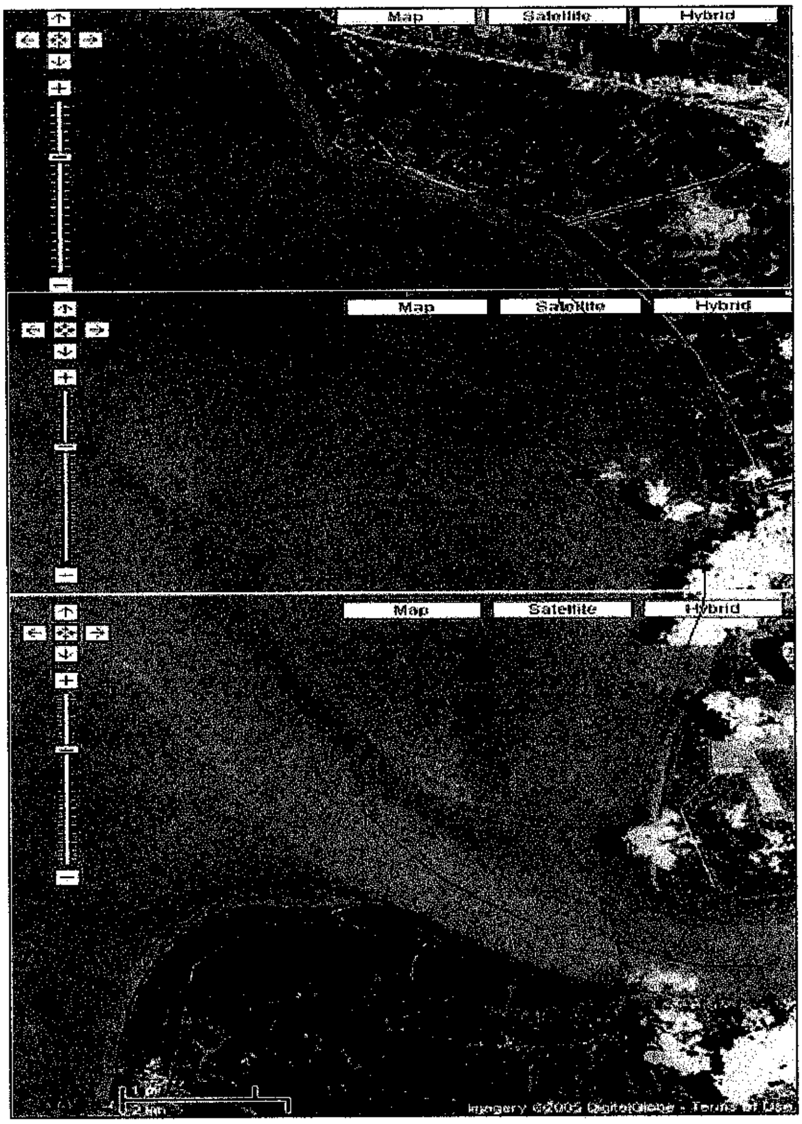


Figure 3.2: Littoral drift along the coast of Tanjung Kepah

Note: The eye-drop mark indicates the location of Tanjung Kepah

The effects of sedimentation could be seen as the mangrove dies from insufficient water as well as oxygen supply to the root. This is because the sediments accumulate along the beach and eventually overtop mangrove roots. The effect of dying mangrove later could be seen from the erosion activities along the coast because the protective barrier is thinning and the coast is more expose to the destructive waves. Now, Tanjung Kepah mangrove coast turns into a mud and sandy coast. During the site investigation, we could not see the sea water as the mud coast is too wide and far. This is due to the nearshore bathymetry. The bottom slope at Tanjung Kepah is nearly horizontal and flat.

3.3.2 Soil Erosion

Mangrove is a natural protector of coastal area from sea erosion. It provides a barrier that prevents rapid sea waves from wearing the beach off. However, the erosion has been taking place in Tanjung Kepah since the past 40 years. Consequently, 2 acres of the coast has been eroded. According to Mr. Roslan, representative of DID, the rate of erosion is 2 to 3 m per year.

According to DID rules and regulations in protecting the shorelines, there are 3 stages of erosion. Stage 1 is extreme erosion to the shoreline and immediate action has to be taken in order to stop the erosion. This is to prevent any damage to the hinterland or high valued development areas at the coast. Stage 2 is considered as the erosion will take 5 to 10 years to give extreme effect to the coastal area. Stage 3 erosion is the least significant kind of erosion and not much action will be taken to resolve the situation since the coastal area does not economic value or the environment is not greatly affected. Therefore, the erosion occurred at Tanjung Kepah is classified as stage 3 erosion.

3.3.3 Local Activities and Urban Development

The local activities at Tanjung Kepah are fishing, agriculture (oil palm), and aquaculture. The local fisherman will dry the fish of every harvest. These dried fish will be kept for future food supply and also to be sold at market. Besides fish harvesting, the locals also harvest cockles at Tanjung Kepah because Tanjung Kepah coast is mud clay soil and it provides a potential breeding area for cockles. Prawn farming is also one of the local people economic activities in Tanjung Kepah because the sea is calm throughout the whole year and the fertility at that area. There are oil palm plantations at Tanjung Kepah. The farmers received help from government bodies in order to start and improve the agriculture activities. Palm oil has potentially economic value because it has a lot of benefits that can be processed into useful daily products.

The development in Tanjung Kepah is low because Tanjung Kepah does not have significant economic value. The road at Kampung Tanjung Kepah area is just rural one-lane road used by the local residents to move along. There are no road facilities like lamps and signage. Thus, the villagers will usually stay at home because the surrounding is so dark that the visibility level is very low and it will be very dangerous to travel during night time. There is a development in Tanjung Kepah, which is irrigation system. This system helps the local people to stop the saline water from the sea from entering the river that can damage the farms.

3.3.4 Protective Coastal Structure

The local DID authorities installed gabion wall structure, that is shown in **Figure 3.3** and **Figure 3.4,** at the problematic area in order to prevent the soil erosion from becoming worse. Gabion walls are structures placed on banks in such a way as to absorb the energy of incoming waves. The gabions are caged rocks, which capture the feel of non-linearity. It is a collection of individual fragments from the same geological time tied together by wire. The gabion wall structure uses granite rocks in the shape of cuboids and they are arranged in an order. The gabion walls are well-ventilated structures and are ideal for innovative eco-friendly buildings. The purpose of this structure is to protect the agriculture from flooding as the wave run up into the soil behind the coastline. Besides that, the gabion wall structure can preserve the existing shoreline and remove the wave energy from damaging the coastline area. In addition to this structure, there is a fabric, called geotextile that is placed in between the rocks and the soils. It is used to prevent the fine grains from being washed away by the waves through the pores of the granite rocks. It is also used to strengthen the gabion wall structures against the destructive waves.

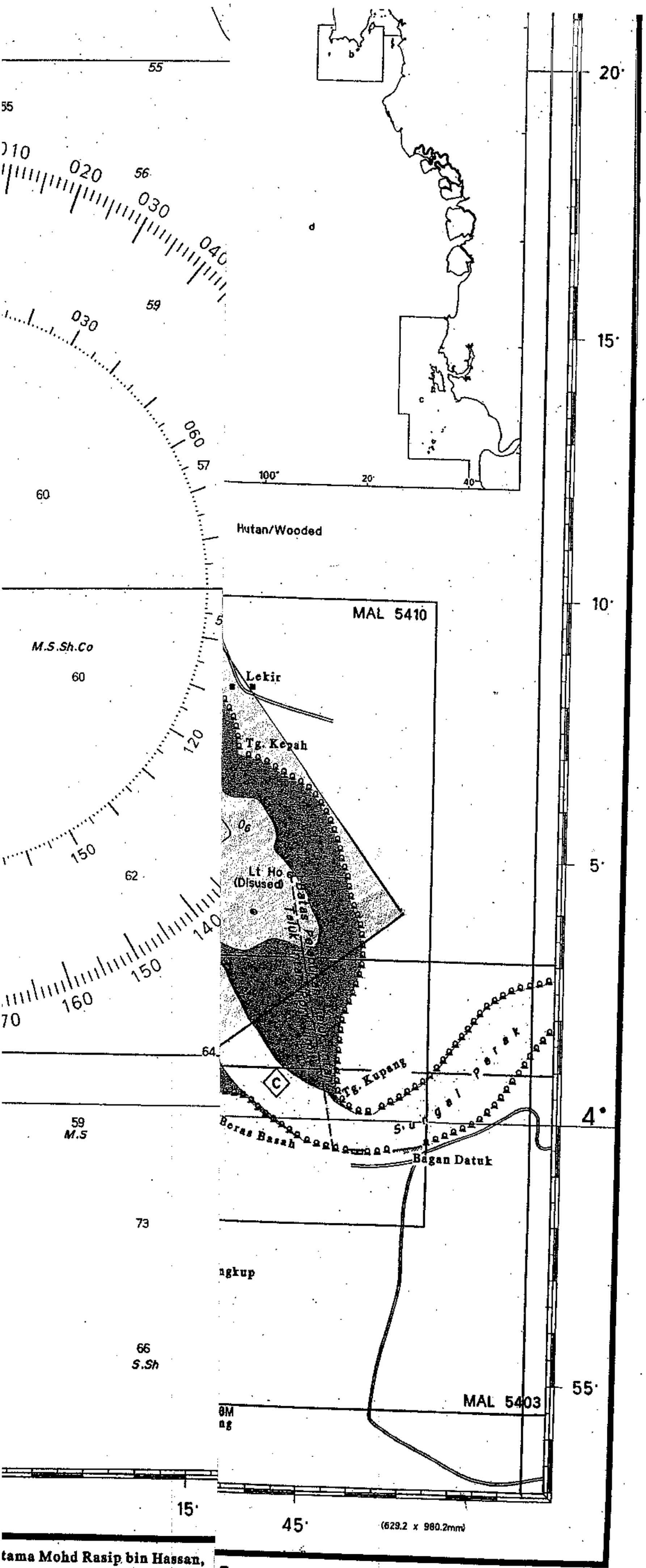
Figure 3.3: Gabion Walls

Figure 3.4: Closer look at gabion walls

3.4 Offshore and Nearshore Bathymetry

The bathymetry of the offshore and nearshore region of Tanjung Kepah can be obtained from Admiralty Chart No. MAL 554 published by Royal Malaysian Navy (15th July 2003) at a scale of 1:200 000 (Lat 4° N) and is indicated in **Figure 3.5.** From the observation of the nearshore bathymetry of Tanjung Kepah coast, the bed gradient is rather shallow and flat. A photo of the flat bed is taken at the study area is shown in **Figure 3.6.**

Figure 3.6: Flat bed slope of Tanjung Kepah beach during low tide



tama Mohd Rasip bin Hassan,
Malaysia.

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MAL 554

3.5 Bed Sampling

Three bed samples of different locations of the coastal area of Tanjung Kepah were taken to be analyzed by using Sieve Analysis Method to predict the soil particles of the coastal area (Refer to **Figure 3.7**).

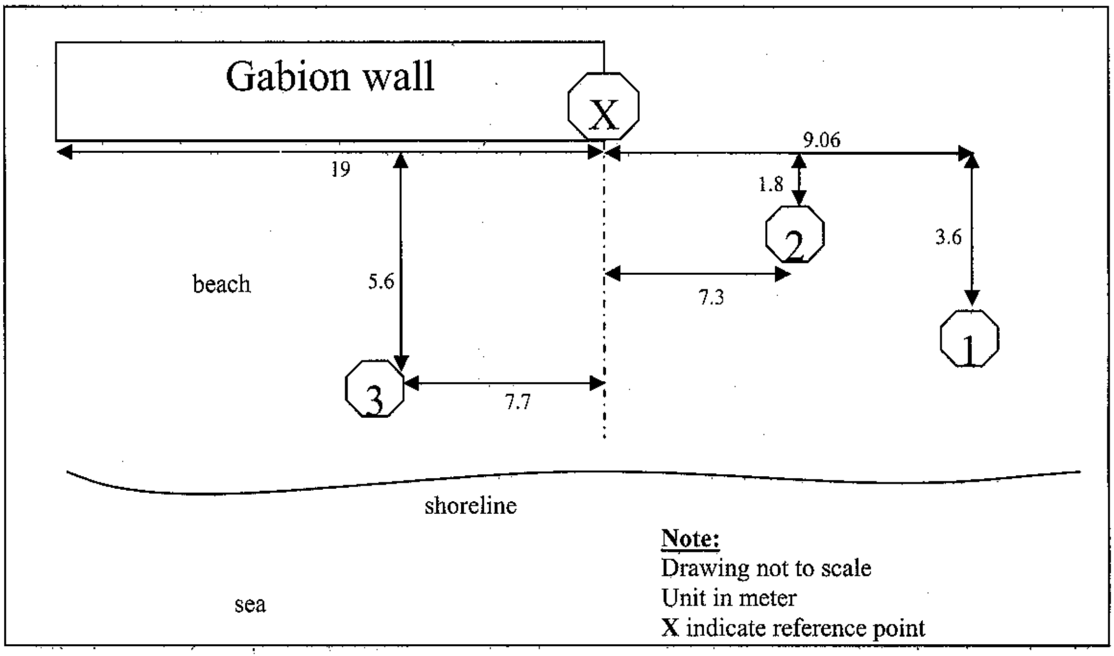


Figure 3.7: Plan view of the coastal area

3.5.1 Soil Sample No. 1

The mass of soil sample retained on the sieves and percentage passing are tabulated in **Table 3.1**. The first sample taken is classified as mainly sand particles as shown in **Figure 3.8**. This sandy sample can be shown in **Figure 3.9**. A level area of sandy beach with small amount of silt and clay along a shore alternately covered or uncovered by the tide or covered by the littoral drift. Material is deposited in this area at times of high tide. From the equation 2.21, the sample is poorly-graded sample as the uniformity coefficient; C_u is 3.6, which is less than 4.

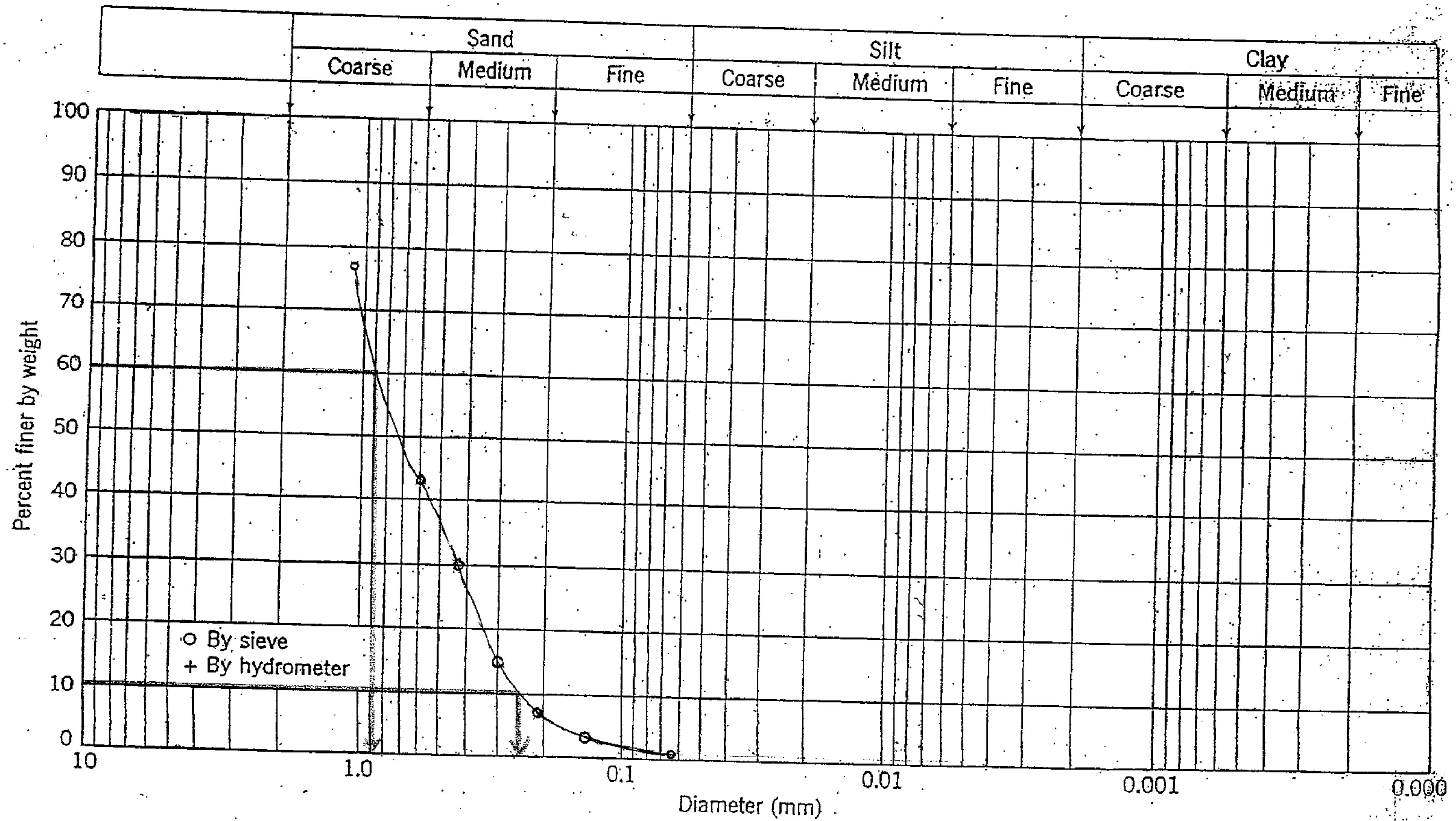


Figure 3-8: Particle size distribution curve. of sample 1

Table 3.1: Sample no. 1 with the initial mass of 0.48 g

Sieve Size (mm)	Mass Of Empty Pan (g)	Pan + Mass Retained (g)	Mass Retained (g)	Percentage retained (%)	Cumulative Percentage Retained (%)	Percentage Passing (%)
1.180	0.437	0.546	0.109	22.71	22.71	77.29
0.600	0.390	0.551	0.161	33.54	56.25	43.75
0.425	0.368	0.434	0.066	13.75	70.00	30.00
0.300	0.356	0.424	0.068	14.17	84.17	15.83
0.212	0.347	0.386	0.039	8.13	92.29	7.71
0.150	0.337	0.356	0.019	3.96	96.25	3.75
0.063	0.327	0.34	0.013	2.71	98.96	1.04
Pan	0.245	0.25	0.005	1.04	100.00	0.00

Figure 3.9: Soil sample 1

3.5.2 Soil Sample No. 2

The mass of soil sample retained on the sieves and percentage passing are tabulated in **Table 3.2**. The second sample taken is determined as mainly sand particles as shown in **Figure 3.10**. This sandy sample can be shown in **Figure 3.11**. It is a naturally occurring, finely divided rock, comprising particles or granules ranging in size from 0.062 mm to 2 mm. There are also coarser material of rocks and shingle on the upper beach and have fallen from the gabion walls to the side. From the equation 2.21, the sample is poorly-graded sample as the uniformity coefficient; C_u is 3.08, which is less than 4.

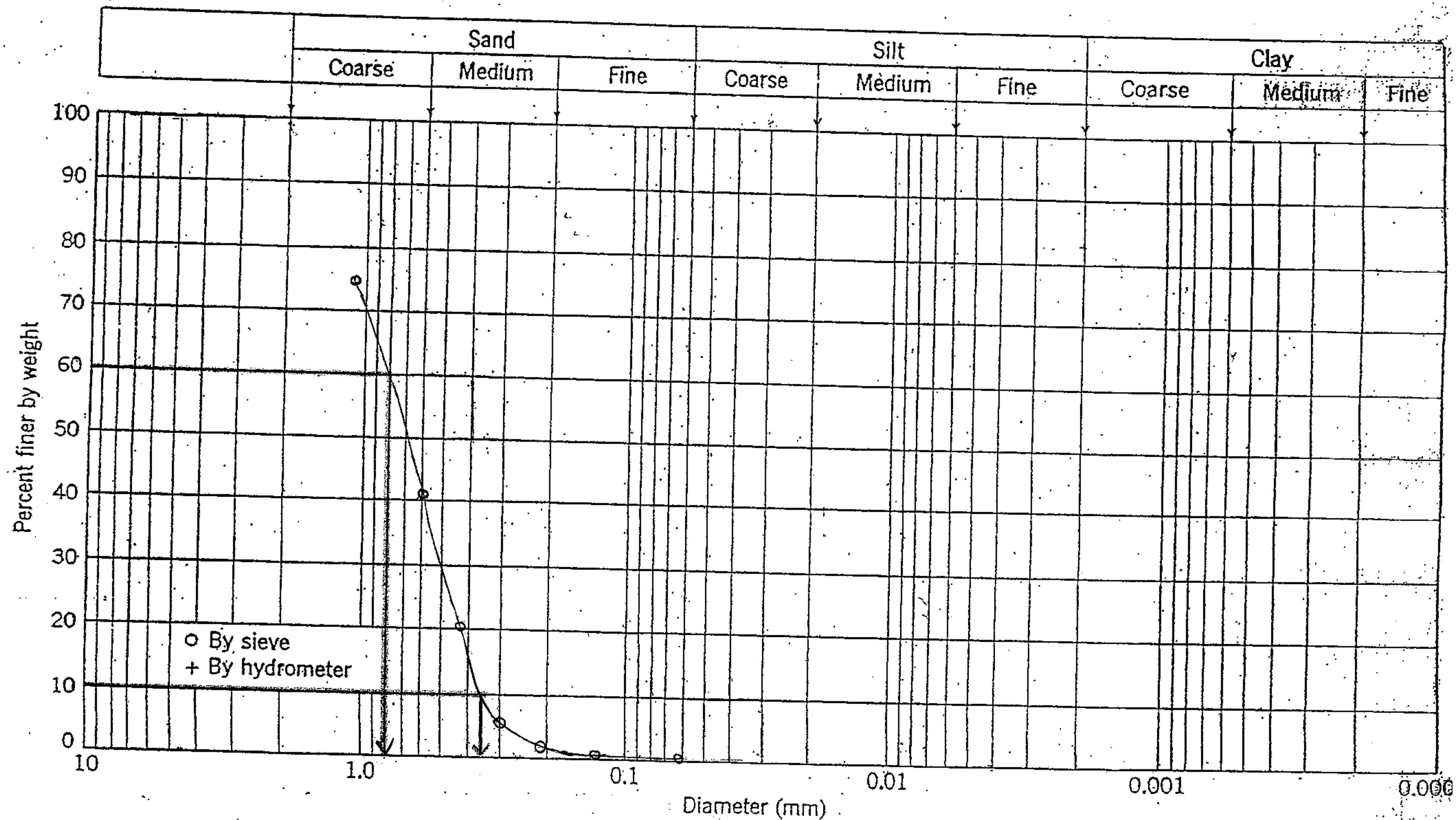


Figure 3.10: Particle size distribution curve. of sample 2

Table 3.2: Sample no. 2 with the initial mass of 0.445 g

Sieve Size (mm)	Mass Of Empty Pan (g)	Pan + Mass Retained (g)	Mass Retained (g)	Percentage retained (%)	Cumulative Percentage Retained (%)	Percentage Passing (%)
1.180	0.437	0.548	0.111	24.94	24.94	75.06
0.600	0.390	0.544	0.154	34.61	59.55	40.45
0.425	0.368	0.456	0.088	19.78	79.33	20.67
0.300	0.356	0.424	0.068	15.28	94.61	5.39
0.212	0.347	0.362	0.015	3.37	97.98	2.02
0.150	0.337	0.342	0.005	1.12	99.10	0.90
0.063	0.327	0.329	0.002	0.45	99.55	0.45
Pan	0.245	0.247	0.002	0.45	100.00	0.00

Figure 3.11: Soil sample 2

3.5.3 Soil Sample No. 3

The mass of soil sample retained on the sieves and percentage passing are tabulated in **Table 3.3**. The third sample taken is categorized as mainly sand particles as shown in **Figure 3.12**. This sandy sample can be shown in **Figure 3.13**. From the equation 2.21, the sample is poorly-graded sample as the uniformity coefficient; C_u is 3.45, which is less than 4.

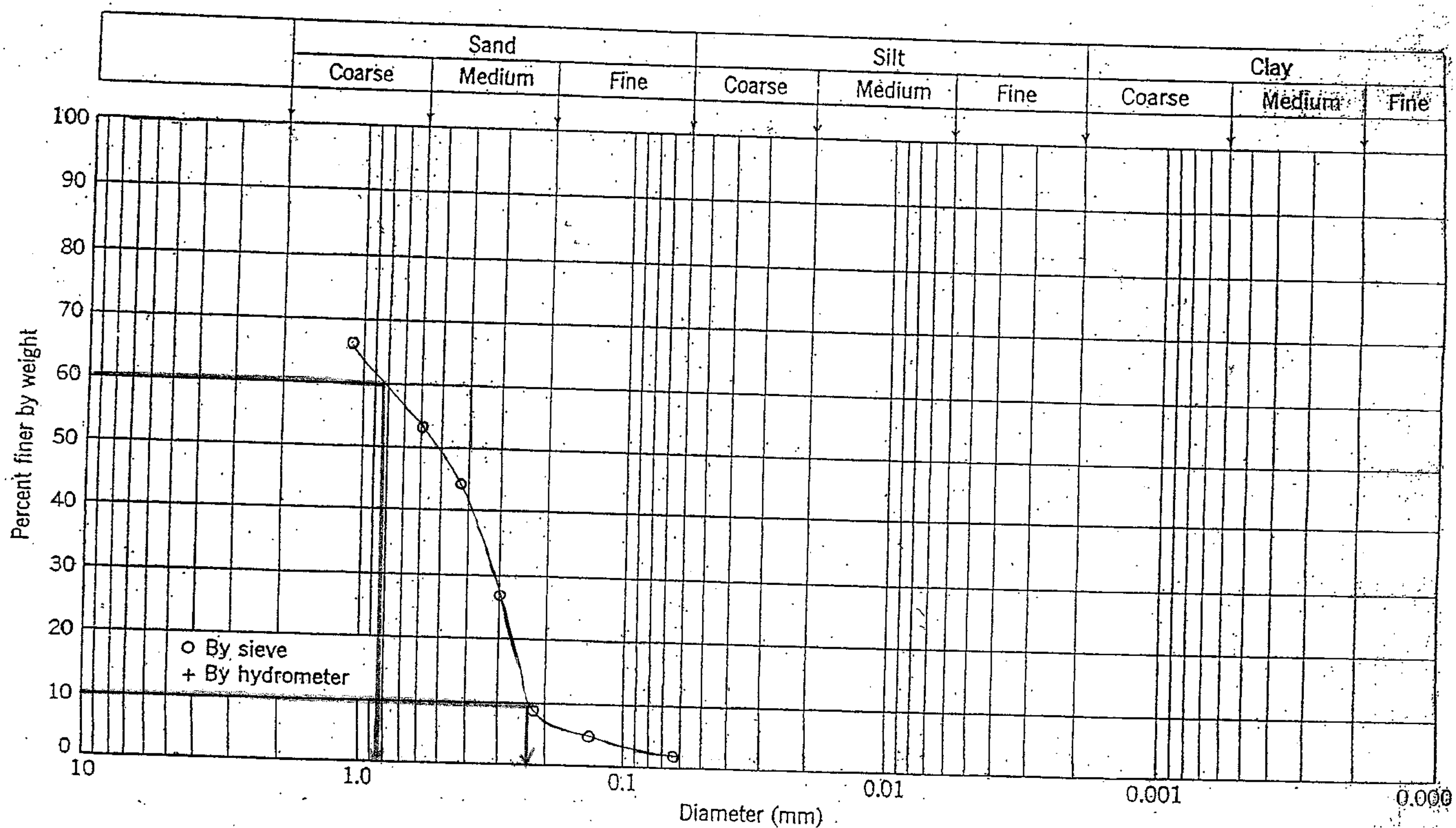


Figure 3.12: Particle size distribution curve. of sample 3

Table 3.3: Sample no. 3 with the initial mass of 0.41 g

Sieve Size (mm)	Mass Of Empty Pan (g)	Pan + Mass Retained (g)	Mass Retained (g)	Percentage retained (%)	Cumulative Percentage Retained (%)	Percentage Passing (%)
1.180	0.437	0.573	0.136	33.17	33.17	66.83
0.600	0.390	0.445	0.055	13.41	46.59	53.41
0.425	0.368	0.405	0.037	9.02	55.61	44.39
0.300	0.356	0.427	0.071	17.32	72.93	27.07
0.212	0.347	0.420	0.073	17.80	90.73	9.27
0.150	0.337	0.355	0.018	4.39	95.12	4.88
0.063	0.327	0.338	0.011	2.68	97.80	2.20
Pan	0.245	0.254	0.009	2.20	100.00	0.00

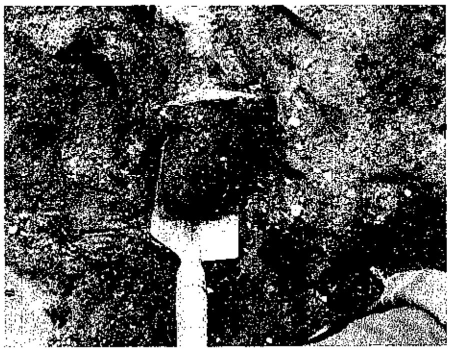


Figure 3.13: Soil sample 3

CHAPTER 4

ENVIRONMENTAL PARAMETERS

4.1 General

A description of the field data and other relevant environmental data collected, reviewed and analyzed around the Tanjung Kepah is presented in this Chapter. The evaluations of the data are necessary so as to establish baseline information to be found in the Existing Condition. In addition to this, sufficient data are also required to serve as boundary inputs into the computer models in order to simulate existing hydrodynamic processes in the water regime before any predictions due to project implementation could be ascertained. Evaluations and appraisal of data pertaining to water level fluctuations, currents, waves, and bed sediments which prevail in the Existing Condition that were acquired from several government agencies.

The wave data is obtained with courtesy from Department of Drainage and Irrigation, Malaysia. Information on wind climate was gathered from Perkhidmatan Kajicuaca Malaysia. Tidal level predictions were also obtained from 2006 Tide Tables for Malaysia published by the Hydrography Department of the Royal Malaysian Navy.

4.2 Tidal Fluctuations

The coastal boundary around the Tanjung Kepah is affected by tidal fluctuations. Tides in the study area a mixed, mainly semi-diurnal, which is two high and low waters each day during most of the time, only one high and low water during neap tides. This can be proven from the tidal data for month March and April by referring to the 2006 Tide Tables for Malaysia published by the Hydrography Department of the Royal Malaysian Navy at Lumut. Both of these data are shown in **Appendix 3-2** and **Appendix 3-3**. Full details of the tidal levels throughout the whole year 2006 in Lumut can be referred to **Appendix 3-4**.

The standard port closest to the site is Lumut in Perak. For easy reference, values of the tidal conditions at the standard port have been tabulated in **Table 4.1**. These values will be used as the reference for the tide levels at Tanjung Kepah. Full details of the tidal levels at standard ports can be referred to **Appendix 3-1**.

Table 4.1: Predicted tide levels and tidal ranges at Lumut Standard Port around the study area

Description	Abbreviation	Predicted Levels (m)
Highest Astronomical Tide	HAT	3.47
Mean High Water Springs	MHWS	2.97
Mean High Water Neaps	MHWN	2.26
Mean Sea Level	MSL	1.87
Mean Low Water Neaps	MLWN	1.47
Mean Low Water Springs	MLWS	0.77
Lowest Astronomical Tide	LAT	0.00
Description		Predicted Tidal Range (m)
Maximum Tidal Range (m)		3.47
Springs Tidal Range (m)		2.20
Neaps Tidal Range (m)		0.79

Plots of tidal data against a time series for March and April are illustrated in **Figure 4.1** and **Figure 4.2**. From the **Figure 4.1**, it is observed that a tidal range of about 2.3 m during spring condition and 1.0 m during neap condition. As for **Figure 4.2**, it is observed that a tidal range of about 2.4 m during spring condition and 1.1 m during neap condition. Water level variations that are taken from the predicted tide levels will be used as inputs in the MIKE 21 Model for generating the hydrodynamic processes in the present study.

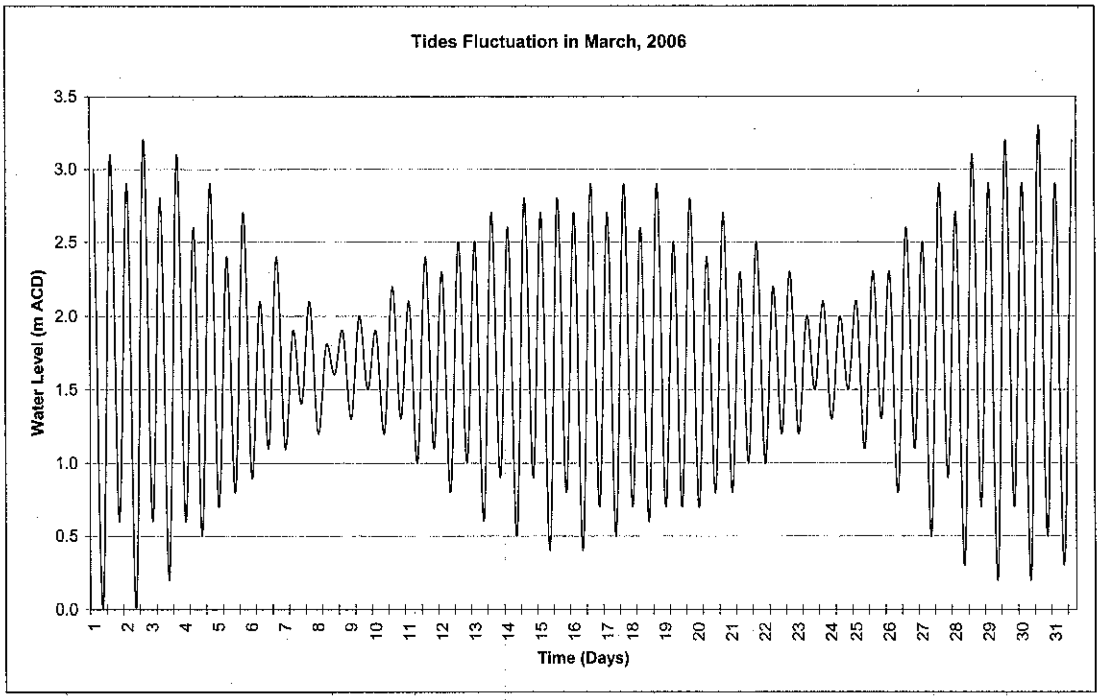


Figure 4.1: Tides Fluctuation in March, 2006

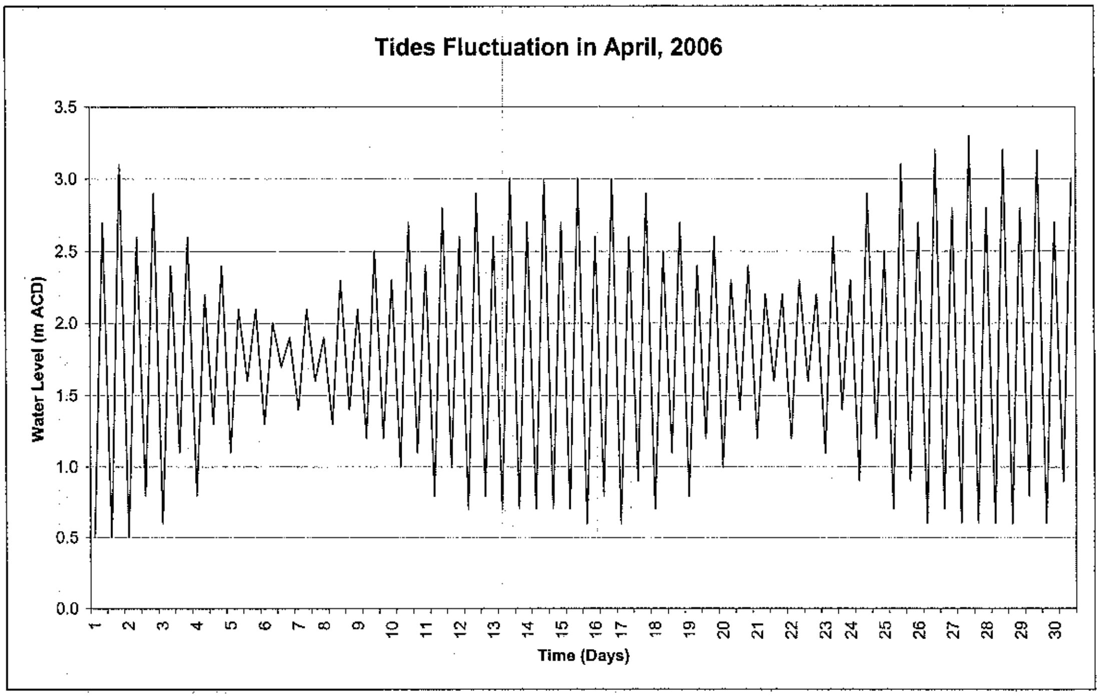


Figure 4.2: Tides Fluctuation in April, 2006

4.3 Tidal Currents

Current magnitudes need to be ascertained in order to assess the movement of wave around the study area. In-situ current measurements must be made available to serve as inputs into the computer model, for calibration or verification purposes and also to generate the synoptic current distribution patterns initially in the Existing Condition. Unfortunately, the in-situ current measurements cannot be conducted as this equipment is not available at this moment. Besides that, this current data at the study area cannot be obtained from the government departments.

In the present study, the current data is obtained from a man-made island project that is currently developing its land reclamation. This man-made island is known as Marina Island. The Marina Island is one of the Malaysia's premier human-made islands, which are being built on the coast of Teluk Muruh, opposite Pangkor Island and Pangkor Laut, in the state of Perak, Malaysia. The project is handled by Marina Island Development Sdn Bhd. The project has reclaimed from the sea with total sea of 316.9 acres, 400 meters from the mainland's shoreline. The project will house a dynamic mix of property development consisting ofresidential, commercial, leisure, and entertainment activities. This data is the only available data that can be used for our project as these current measurements were conducted at Teluk Muroh, about 20km away from Tanjung Kepah.

The current data from Teluk Muroh is measured from the simulated spring tide flow patterns for peak northward flow (Ebb) and peak southward flow (Flood) in **Appendix 3-5** and **Appendix 3-6** respectively. After that, these data is tabulated and the average current speeds for both flows are calculated and shown in **Appendix 3-7** and **Appendix 3-8**. This raw data is calculated and summarized in **Table 4.2.** From the table, the average current speed that occurs during ebb tide is 0.4604 m/s at 335° and during the flood tide; the average current speed is 0.4625 at 145°.

Table 4.2: Spring tide flow patterns after the reclamation construction

Tide flow pattern	Condition	Current Direction	Current Speed, Vavg (m/s)
Peak northward flow (Ebb)	After reclamation construction	335 Degrees	0.4604
Peak southward flow (Flood)	After reclamation construction	145 Degrees	0.4625

4.4 Wind Climate

The wind climatic conditions in Malaysia are characterizes by two monsoon periods and correspondingly two successive inter-monsoons such that the following become apparent:

- North-East Monsoon Season (November to March)
- Inter-Monsoon or Transitional Season (April to May)
- South-West Monsoon Season (June to early October)
- Inter-Monsoon or Transitional Season (late October to early November)

During the North-East Monsoon, northerly and north-easterly winds are dominant, whereas southerly and south-westerly prevails during the South-West Monsoon periods.

Wind climatic conditions in the study area would be similar to that found at the nearest meteorological observation station, which is at Sitiawan. Wind observations at the station are taken from pressure tube anemograph. Wind direction is analyzed according to the 8 compass points. The limits chosen for wind speed correspond with the scale for Beaufort Force. The source data used in the analysis are the hourly averages of wind speed and direction. This analysis will be used to record the monthly maximum surface wind for various years. Therefore, the records of monthly maximum surface wind at Sitiawan station (1968 to 2005) are illustrated in **Appendix 3-9**.

Wind rose diagram is the concentric circles in dashes of a wind rose represent the various percentage frequencies of time as labeled. The innermost full circle represents the percentage occurrence of calm (wind speed less than or equal to 0.2 m/s), the value of which is inscribed within the circle. Various arms radiate from the innermost circle. The total length of each arm represents the total percentage frequency of time the wind blows from the direction concerned. Each arm is again subdivided into a line and rectangles of different shades or sizes. These represent the various classes of speed as given in the key scale.

A monthly maximum surface wind summary for various years from 1968 to 2005 has thus obtained from the Malaysian Meteorological Service at Kuala Lumpur to describe the prevailing wind climate in the area. A typical mean annual wind speed recorded at Sitiawan station is summarized in the wind rose diagram in **Appendix 3-10**. The wind rose summary for different seasons (1968 to 2005) is also shown in **Appendix 3-11.** Details of the percentage frequencies of winds blowing from various directions and speeds during the North-East and South-West Monsoon periods have been summarized in **Appendix 3-12**.

The wind rose diagram and percentage frequency of occurrence as shown in **Figure 4.3** and **Appendix 3-12** indicated that during the South-West Monsoon (May – September), southerly wind prevails. This wind accounts for 11.8% of the whole wind occurrence. Maximum winds speeds varied between 3.4 m/s and 5.4 m/s. these winds are rare, occurring for only 11% of the times. Winds are calm for 35.6% of the times with speeds being less than 0.3 m/s. Winds blowing with a mean speed of 1.6 m/s to 3.3 m/s are common with 27.2 %. They blow from the southerly direction mostly.

During the North-East Monsoon season (November – March), westerly wind is more common and predominant. Kindly refer to **Figure 4.4** and **Appendix 3-12.** Westerly winds account for an estimated 12.2% of the whole occurrence time. Recorded maximum speeds that are attained between 3.4 m/s and 5.4 m/s for about 18% of the times. Wind conditions are calm at speeds less than 0.3 m/s for 41% of the whole wind occurrence period. Winds blowing with a mean speed of 0.3 m/s and 1.5 m/s are common with 28.5%. They blow from the north-easterly direction mostly.

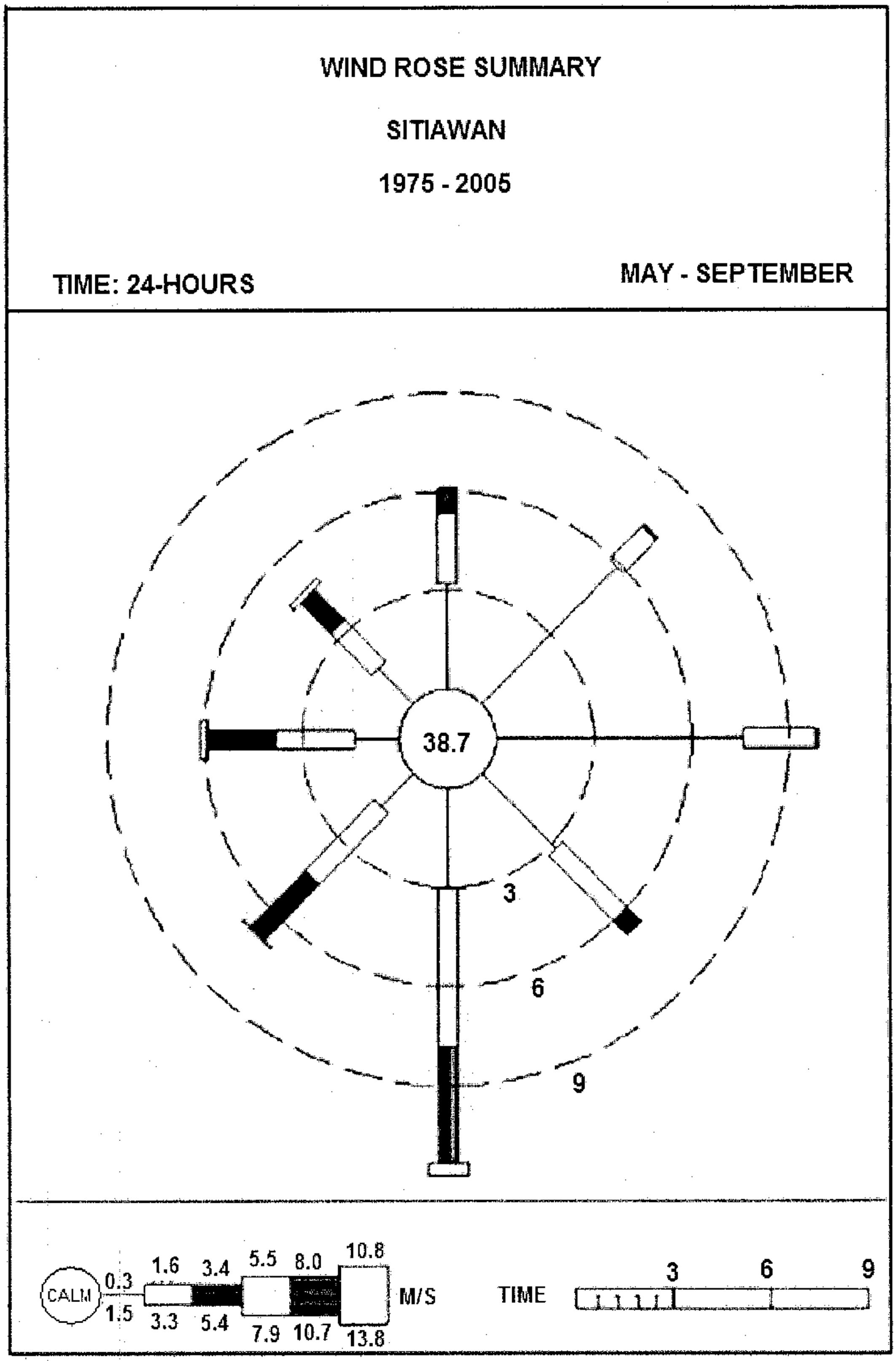


Figure 4.3: Wind rose of South-West Monsoon

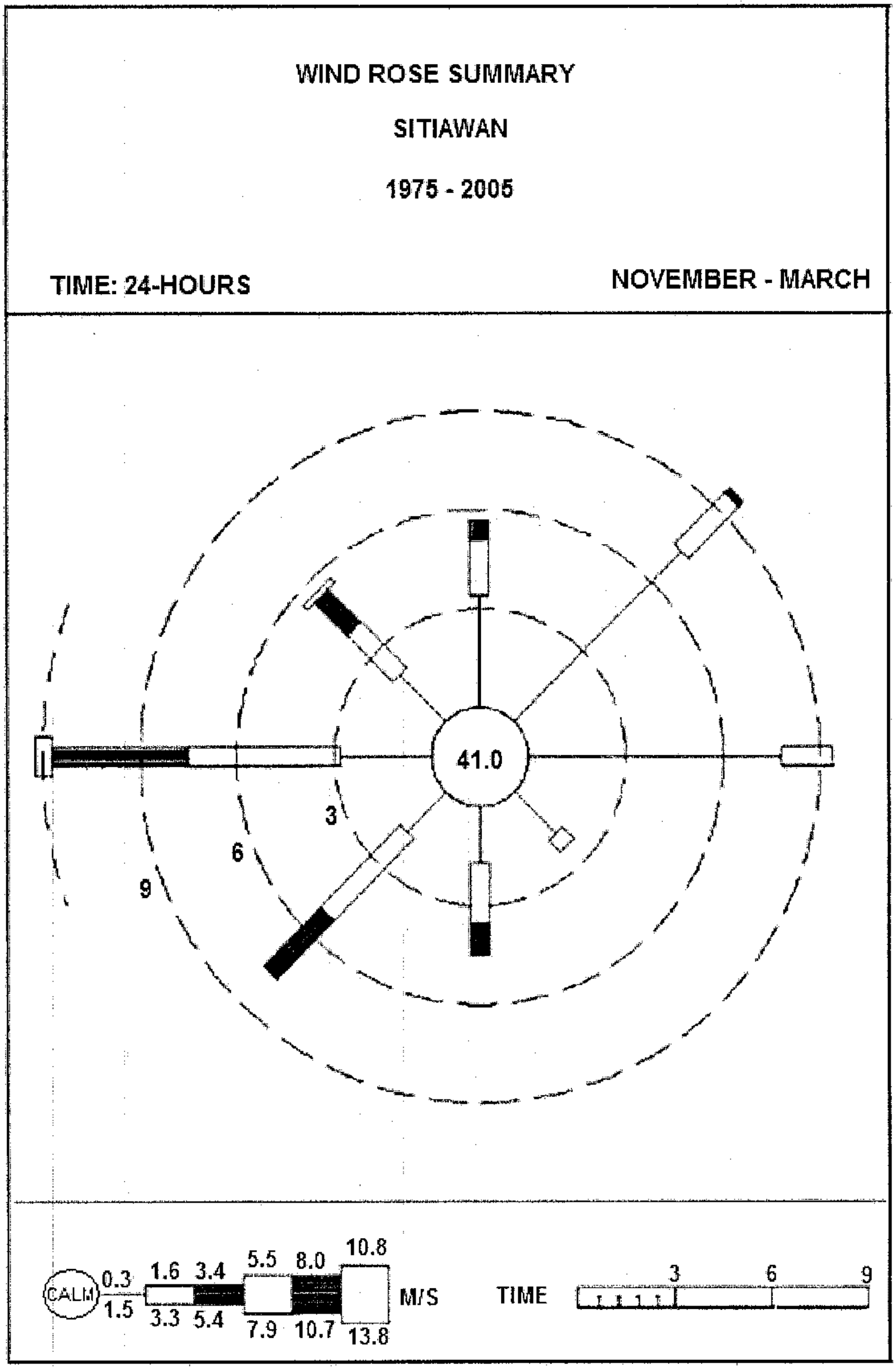


Figure 4.4: Wind rose of North-East Monsoon

Wind data considered at Sitiawan observation station above are generally representative and should characterize those prevailing at the study area. This wind data will be considered as inputs into the modeling simulations. According to the records of maximum surface wind from 1968 to 2005 at Sitiawan observation station, which are illustrated in **Appendix 3-9**, the most extreme wind velocity for the past 38 years period was recorded to be 28m/s. This wind occurred in the year 1970 and blow from the 100° direction.

4.5 Wave Climate

Tanjung Kepah is geographically located in the middle of West Coast of Peninsular Malaysia and it is exposed to Melaka Straits. Tanjung Kepah has natural protective barriers, which are Pulau Pangkor and Kepulauan Sembilan. Tanjung Kepah is exposed to both waves and swells. The relevant exposure window for waves is 150° to 330°.

Waves are disturbances caused by energy moving through water mater mass. Energy moves, but water does not. The disturbing forces are wind, displacement (earthquake, land slide and tsunami), changes in atmospheric pressure and gravitational pull of sun/moon. There are also the restoring forces that are dominantly trying to return the water surface to flat by surface tension, capillary force and gravity. The simplest form of wave is sinusoidal but actual shape is very complex. Swell is a type of wind-generated waves. Swells are waves that have traveled over hundreds or thousands of mils from the generated area. They have low steepness and long wavelength.

Field measurement of wave data at the study are is non-existent at present. Therefore, the wave climate data relevant to the study area has been obtained from the wave data bank of Coastal Engineering Department, Department of Drainage and Irrigation, Malaysia. Full details of the wave statistics summaries of waves and swells for Annual, North-East Monsoon and South-West Monsoon periods are shown in **Appendix 3-13** until **Appendix 3-15**. Besides that, full details of the maximum monthly wave height for various years and directions are shown in **Appendix 3-16**. These data are originated from the various sectors, where the Marsden Squares are numbered as 2630, 2640, 2650, 2739, 2749, and 2759. The results of the wave climate are summarized as deep water wave roses as shown in **Figure 4.5** and **Figure 4.6**.

Waves are relatively strong during the South-West Monsoon period with waves approaching at the angle of 300° sector, reaching a maximum range of greater than 4.25 m statistically. They occur for 0.2% of the times when approaching 300° directions. Corresponding wave periods are greater than 10 seconds. Wave height smaller than 0.75 m at corresponding periods 4 to 5 seconds has the most occurrences, which is 7.4% of the times. These waves have a predominant deep water wave approach direction from the 300° angle as shown by the wave rose diagram of annual period in **Figure 4.6.**

Wave analysis has been carried out to find the significant wave height (Hs), Hrms, significant wave periods (Ts), and Trms. Full details of the calculation of Hs, Hrms, Ts and Trms are shown in **Appendix 3-17**. These data are tabulated in **Table 4.3**. Besides that, the wave heights and wave periods are plotted against directions respectively as shown in **Figure 4.7** and **Figure 4.8**. From the analysis, the highest significant wave height is 2.1 m, which occurred at 300°. Correspondingly, the wave period at 300° is 8.2 seconds. This wave analysis data will be considered as inputs for the computer modeling.

Table 4.3: Wave heights and wave periods for various degrees

Wave Directions (Degrees)	Hs (m)	Hrms (m)	Ts (s)	Trms (s)
150	1.5833	1.1477	7.2292	5.7657
180	1.4878	1.1098	7.4268	5.8880
210	1.4432	1.0333	7.9773	6.1615
240	1.5513	1.1396	6.5897	5.3676
270	1.6735	1.2359	8.1224	6.1787
300	2.0938	1.5590	8.1667	6.3645
330	1.9074	1.4230	8.0926	6.2160

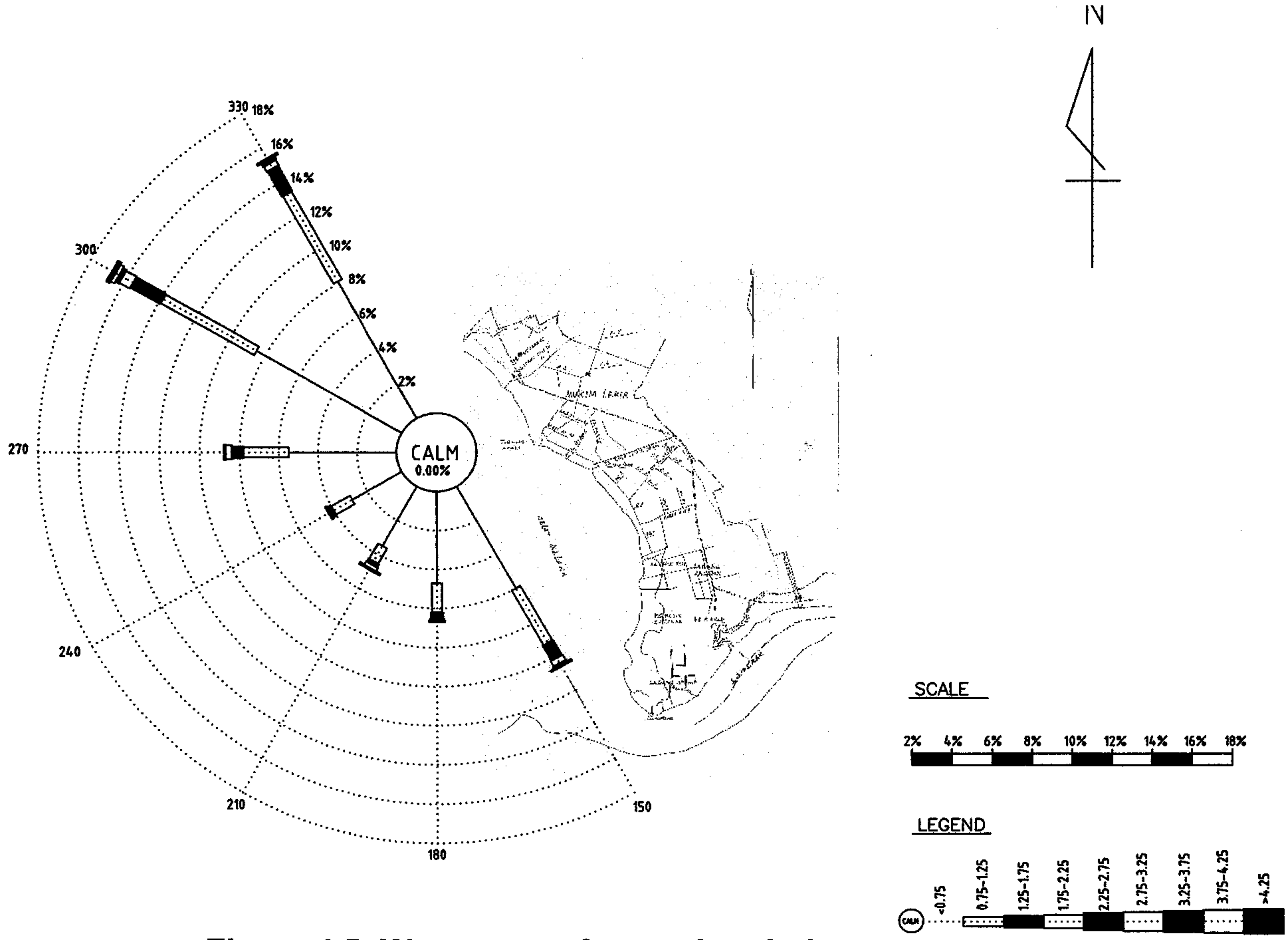


Figure 4.5: Wave rose of annual period

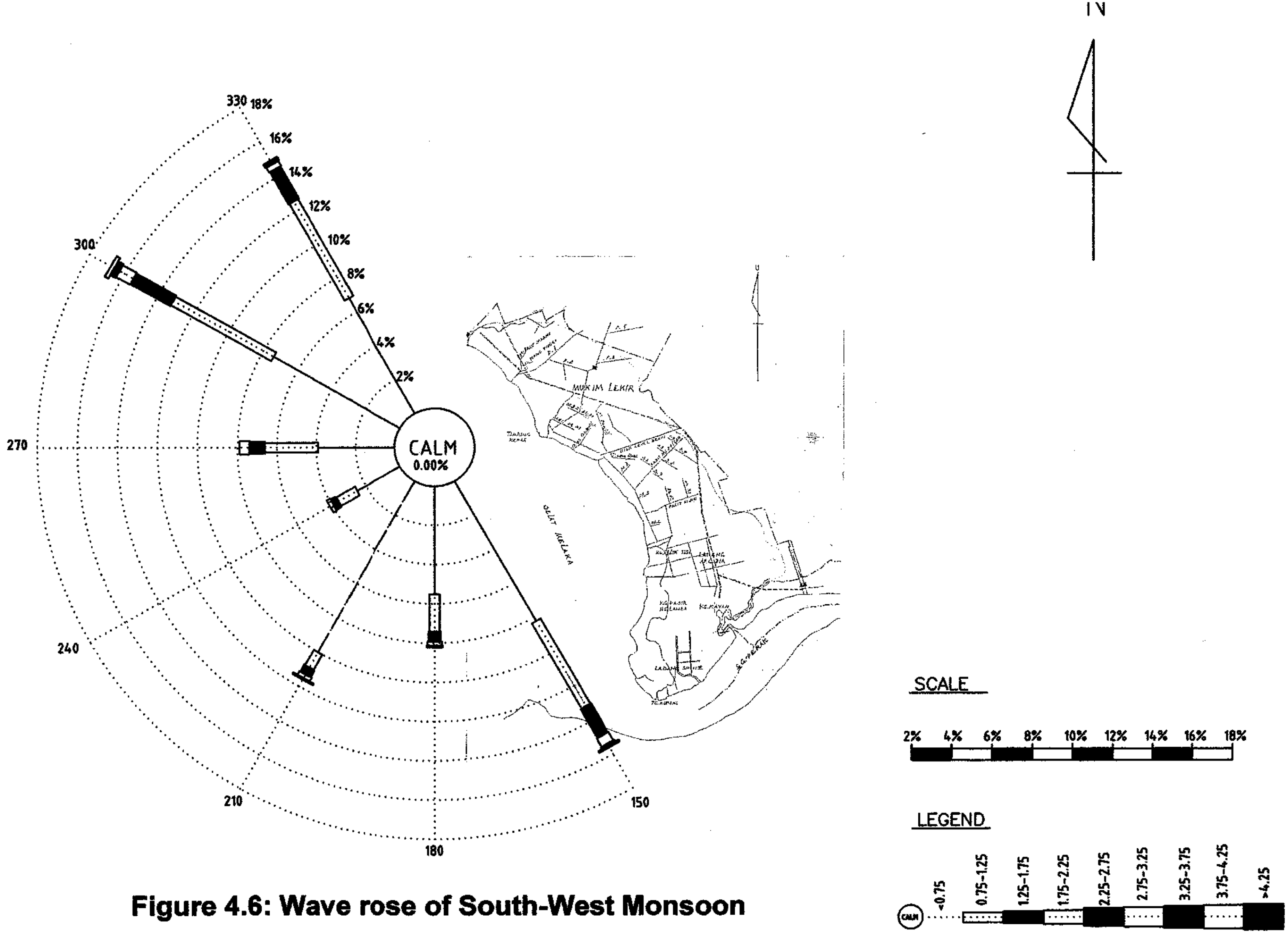


Figure 4.6: Wave rose of South-West Monsoon

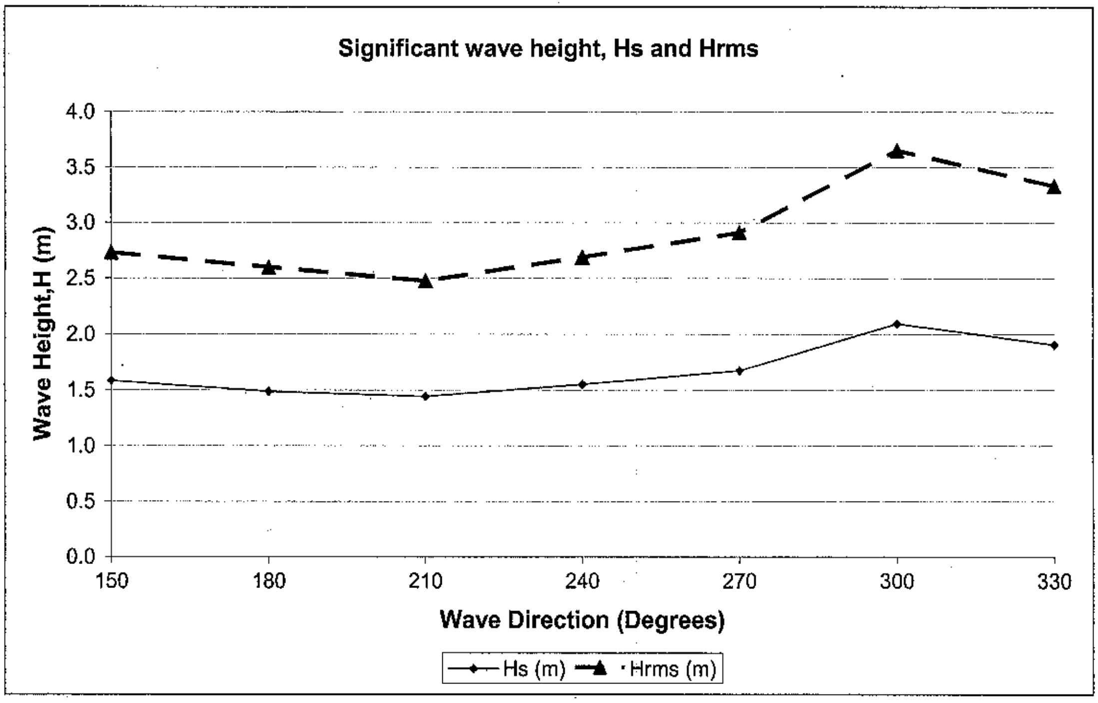


Figure 4.7: Wave heights against directions

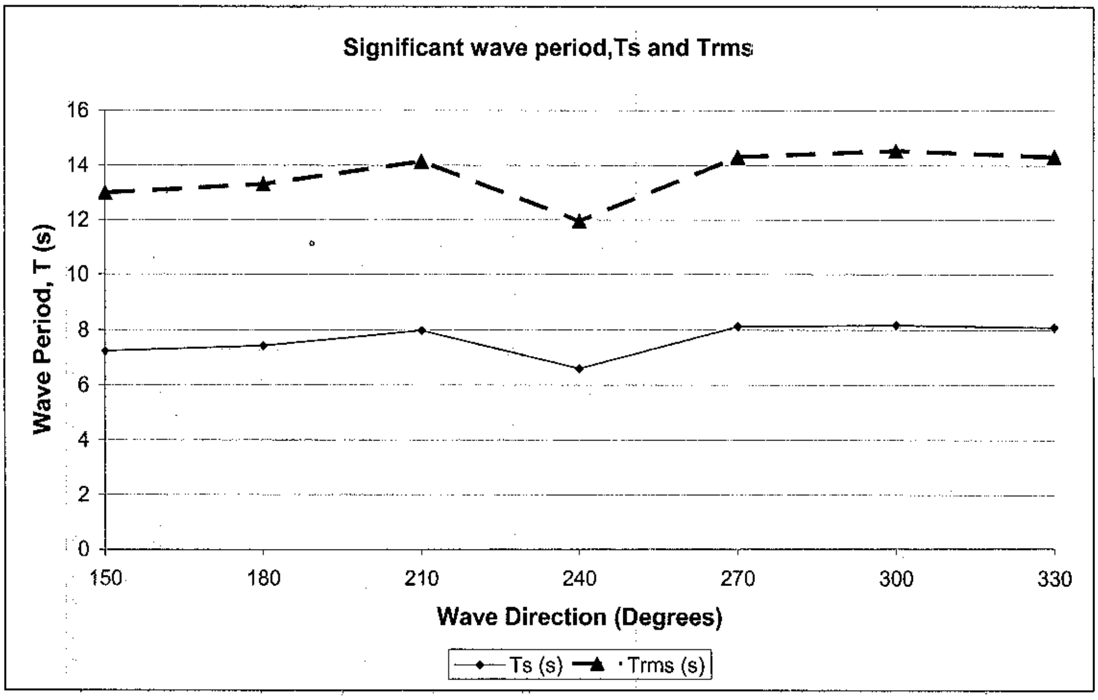


Figure 4.8: Wave periods against directions

Further wave analysis on extreme wave conditions is carried out on the data obtained. The Gumbel Distribution is used to determine deep water wave heights for return period of 2, 5, 10, 20, 50, and 100 years. From the Gumbel Distribution analysis, each wave height direction will produce a best fit linear graph in order to find γ and β. With the values of the γ and β, the predicted extreme wave heights for various return periods can be determined. Full calculations of Gumbel Distribution analysis for wave heights are shown in **Appendix 3-18.** The figures below show the relationship of Gumbel reduced variate, G against wave height, H for various directions.

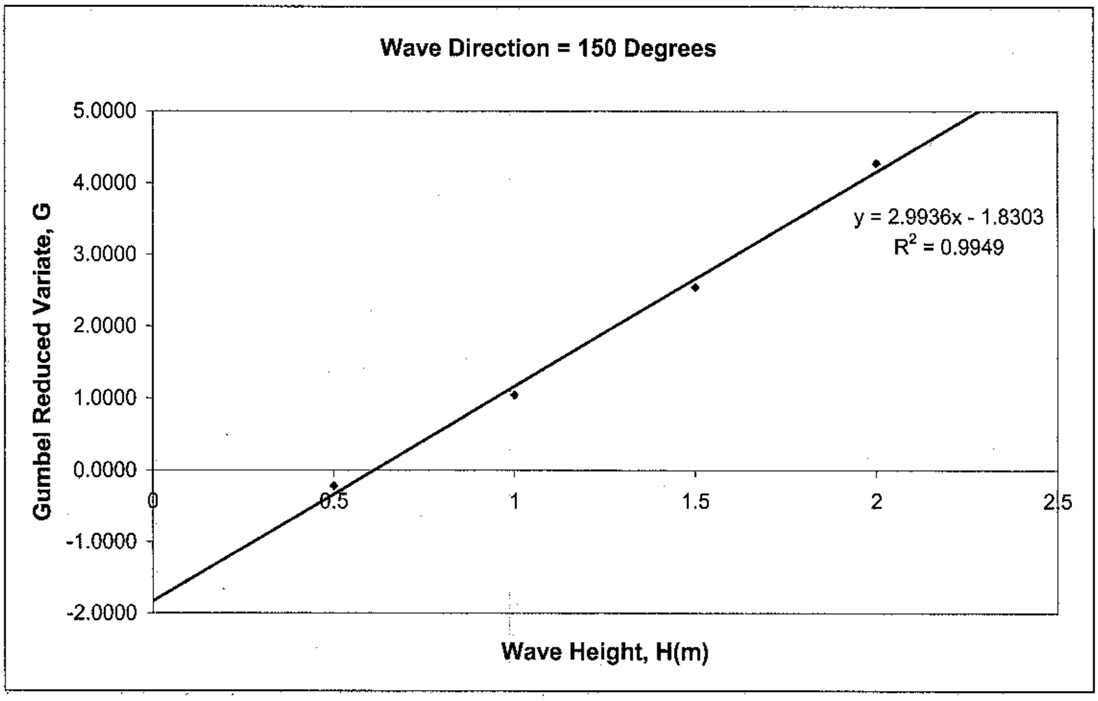


Figure 4.9: Wave height direction at 150°

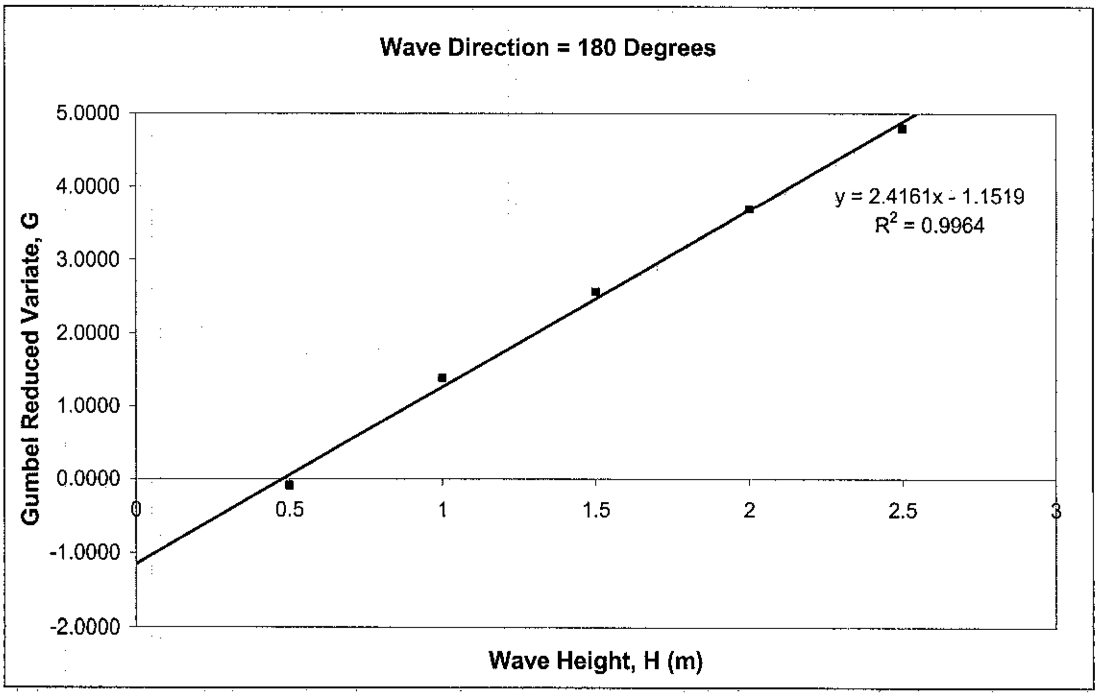


Figure 4.10: Wave height direction at 180°

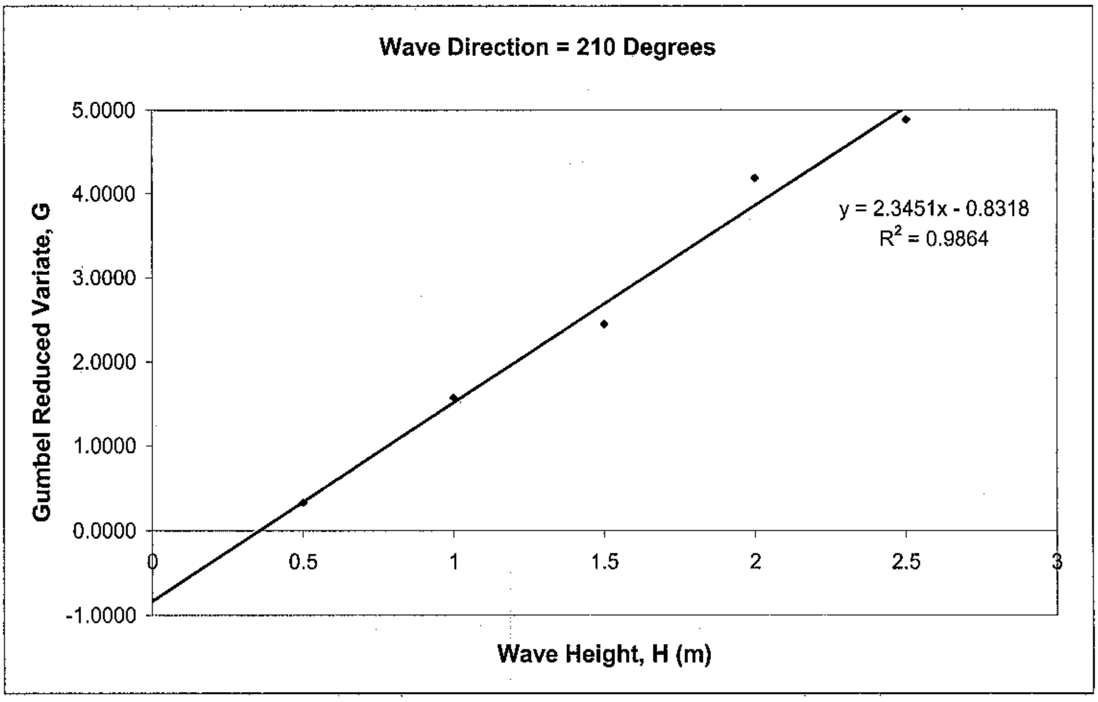


Figure 4.11: Wave height direction at 210°

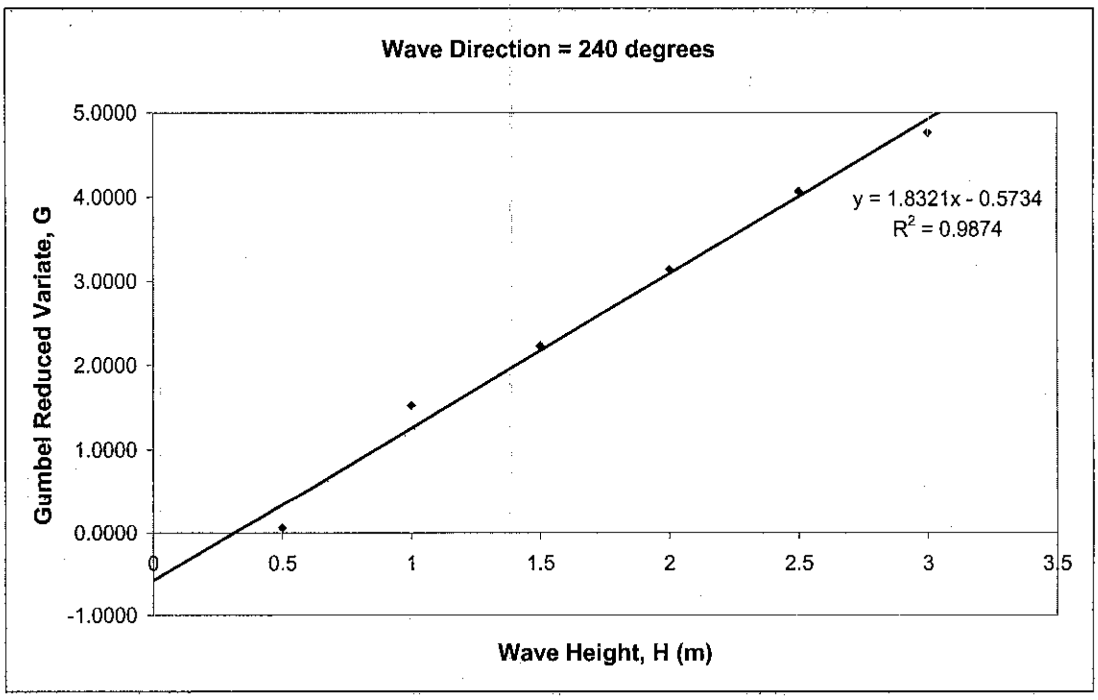


Figure 4.12: Wave height direction at 240°

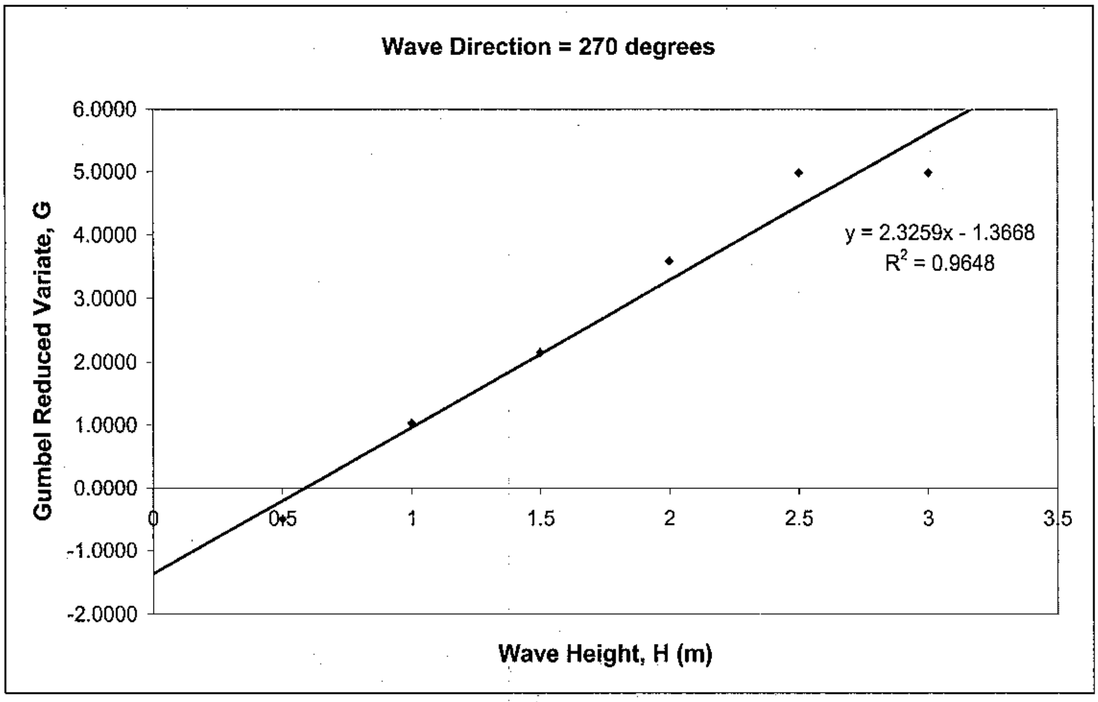


Figure 4.13: Wave height direction at 270°

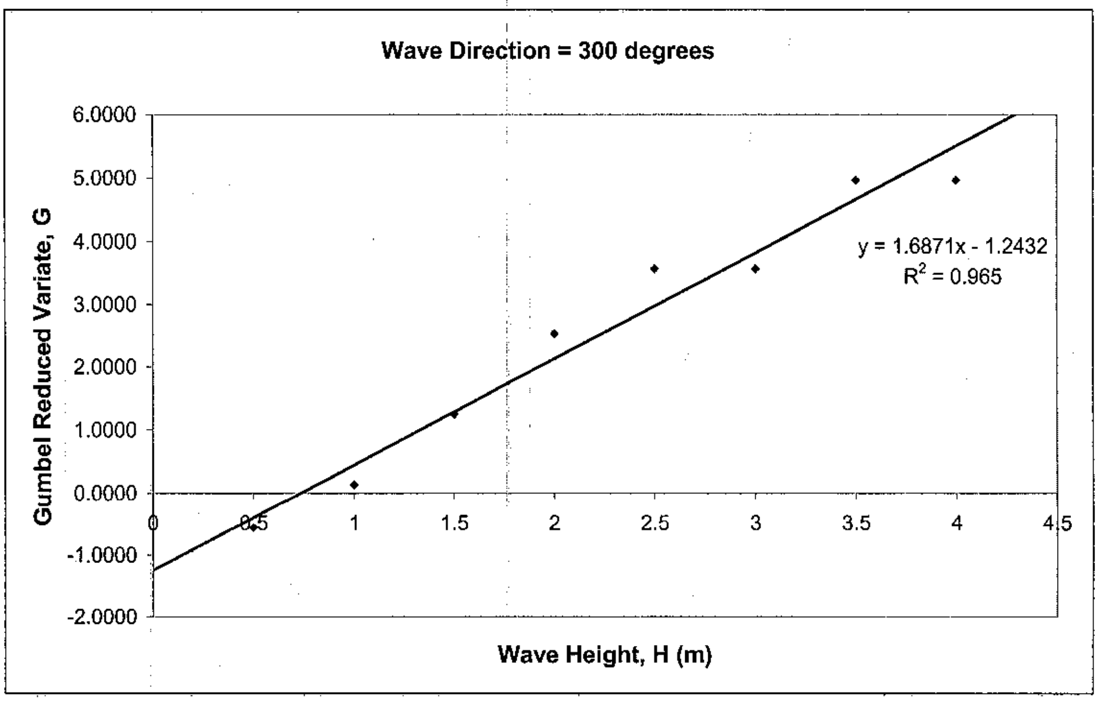


Figure 4.14: Wave height direction at 300°

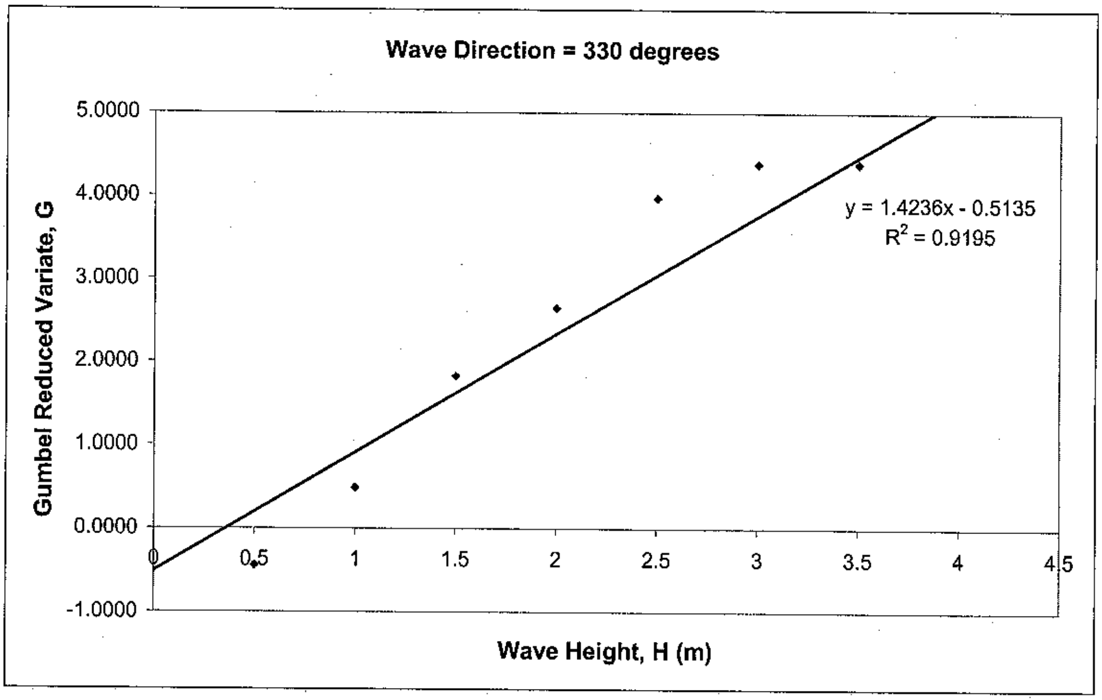


Figure 4.15: Wave height direction at 330°

Results of the predicted wave heights for the various return periods are tabulated in **Table 4.4**. Data used for this analysis were taken from long term wave observations made during the past 37 years (from 1948 to 1984). Results of the corresponding wave heights are illustrated as **Figure 4.16**. From the summary, the most extreme wave heights occur at the direction of 330° with 4.687 m at the return period of 100 years.

Table 4.4: Extreme wave heights of various return periods for various degrees

Wave Direction (Degrees)	λ	β	γ	Wave Height of Various Return Periods (m): 2 years	5 years	10 years	20 years	50 years	100 years
150	4.394	0.334	0.611	1.317	1.635	1.871	2.104	2.412	2.643
180	4.067	0.414	0.477	1.317	1.713	2.005	2.295	2.676	2.963
210	3.912	0.426	0.355	1.203	1.611	1.913	2.211	2.603	2.899
240	3.807	0.546	0.313	1.383	1.906	2.292	2.674	3.176	3.555
270	4.294	0.430	0.588	1.486	1.896	2.199	2.499	2.895	3.193
300	4.500	0.593	0.737	2.005	2.569	2.986	3.401	3.946	4.357
330	4.735	0.702	0.361	1.901	2.568	3.063	3.553	4.199	4.687

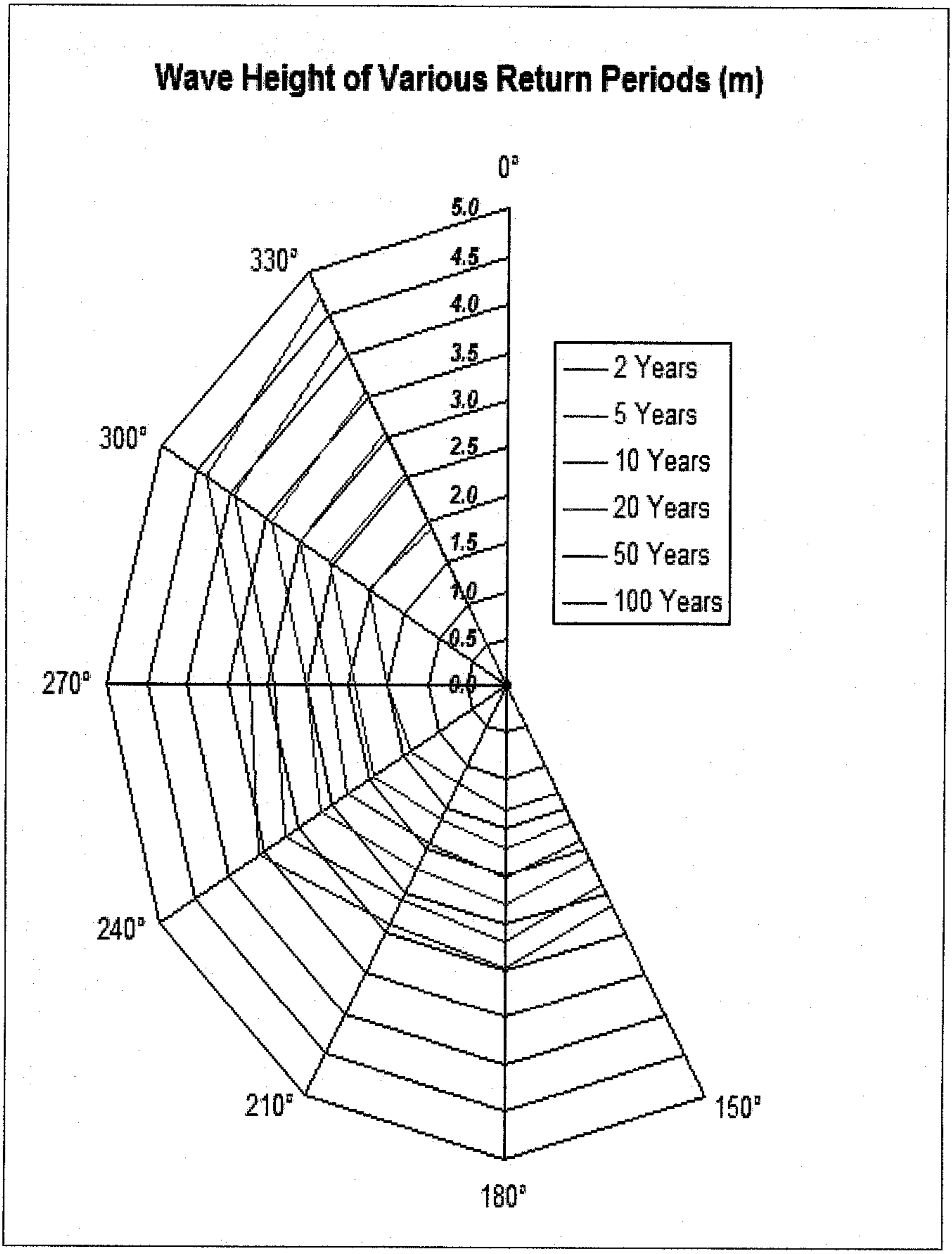


Figure 4.16: Extreme wave heights of various return periods

The Gumbel Distribution analysis is not only done on the wave heights, but also on the wave periods. Full calculations of Gumbel Distribution analysis for wave periods are shown in **Appendix 3-19.** Thus, the results of the analysis are illustrated as figures shown below with various wave period directions.

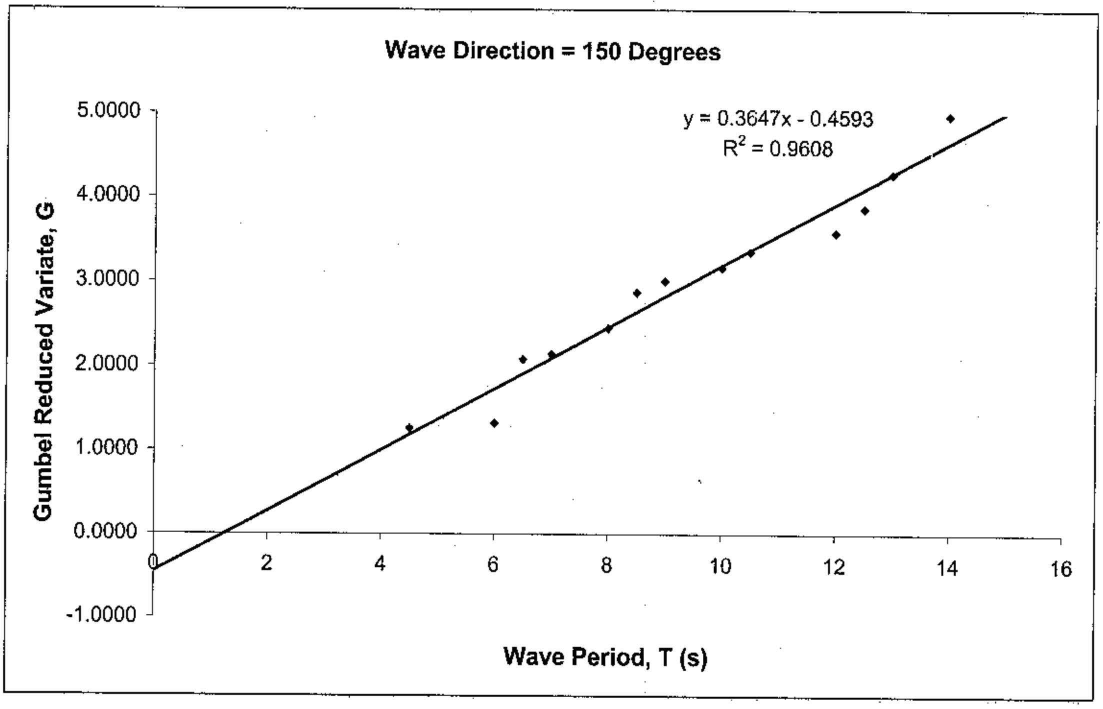


Figure 4.17: Wave period direction at 150°

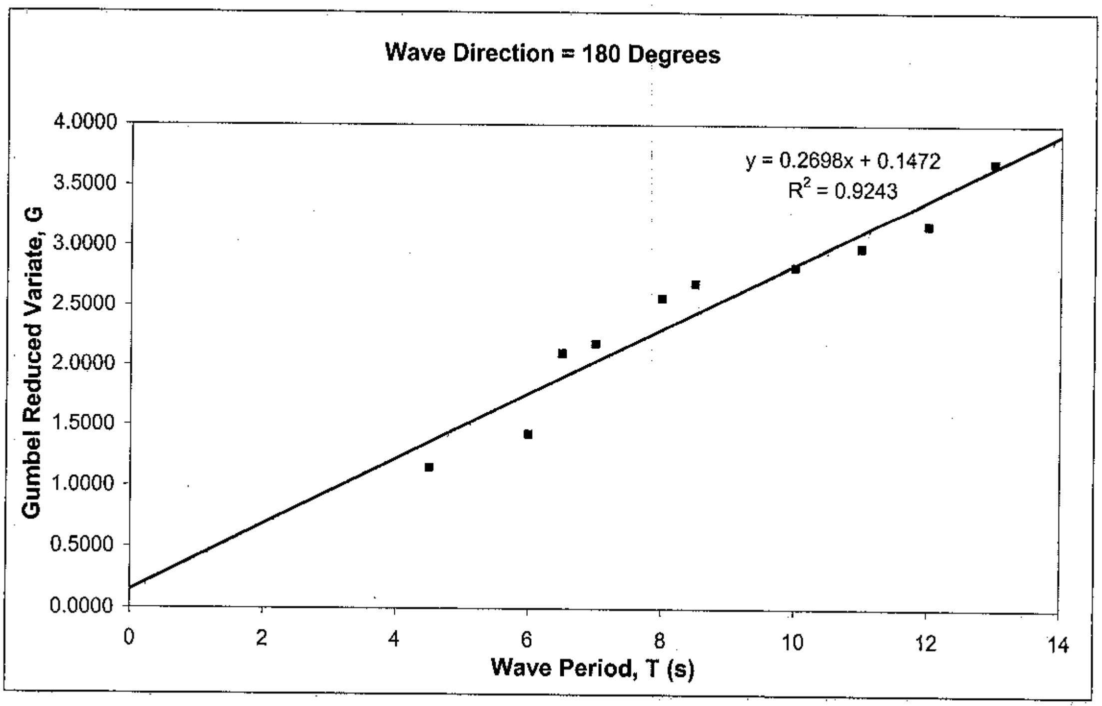


Figure 4.18: Wave period direction at 180°

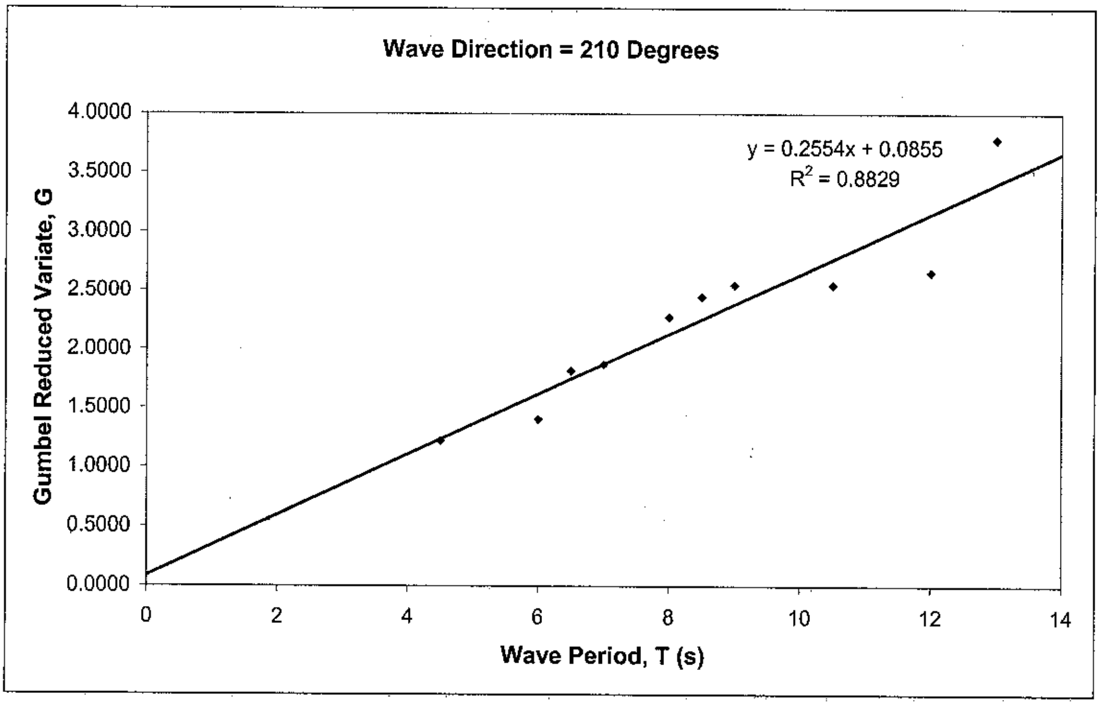


Figure 4.19: Wave period direction at 210°

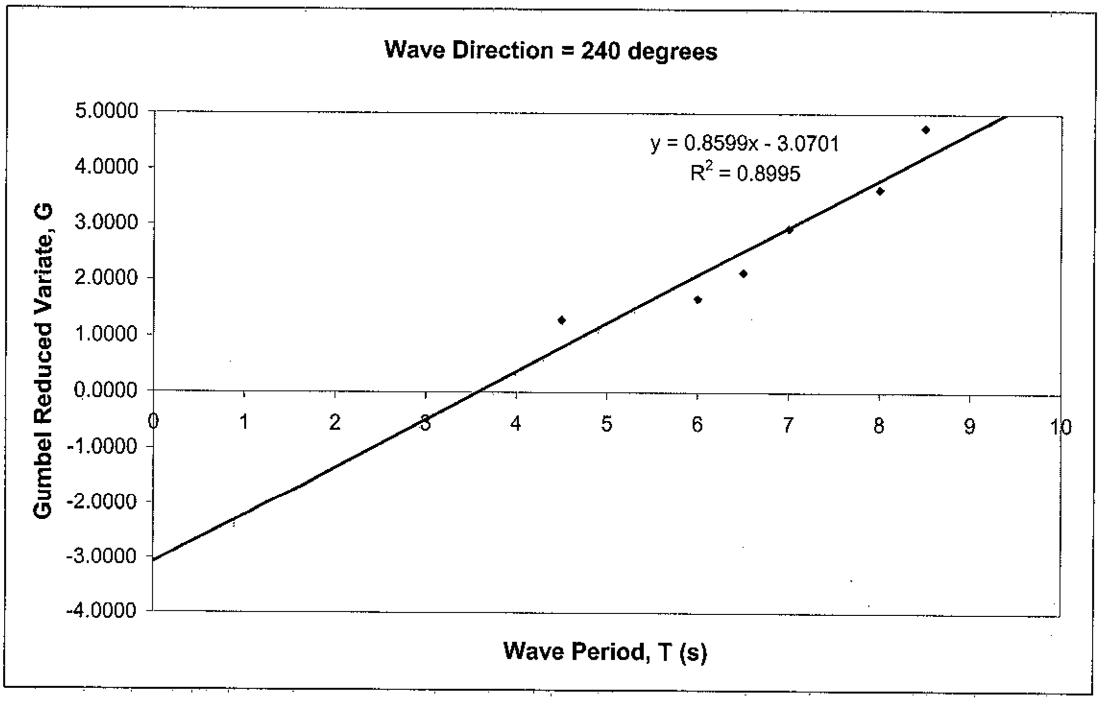


Figure 4.20: Wave period direction at 240°

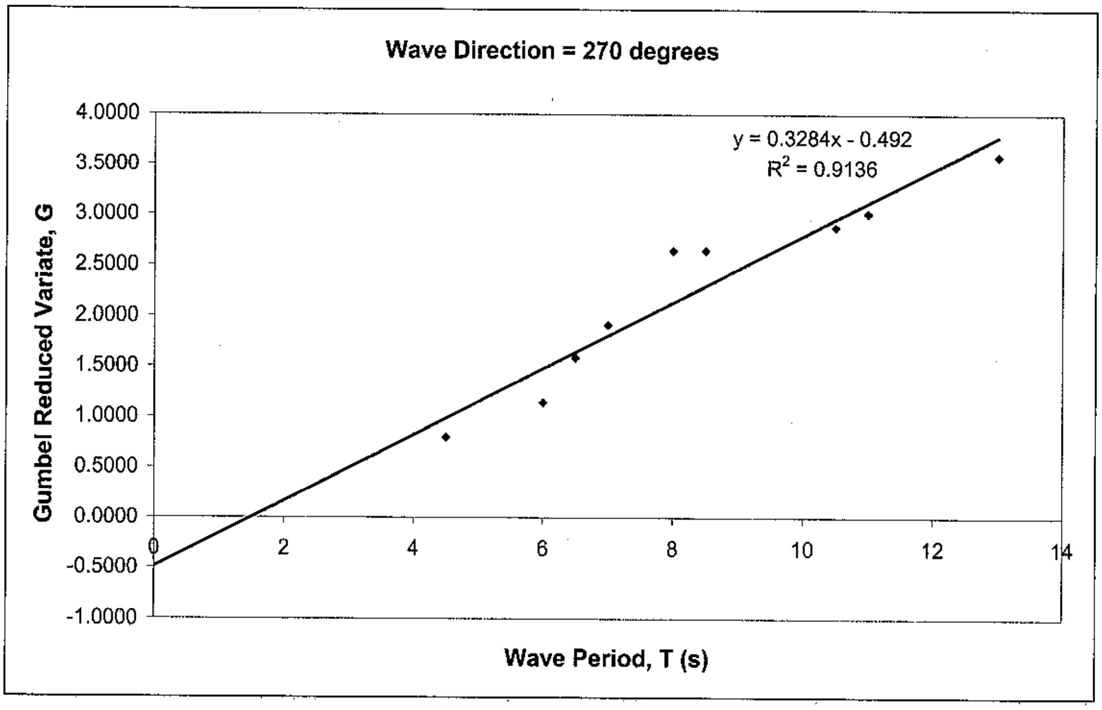


Figure 4.21: Wave period direction at 270°

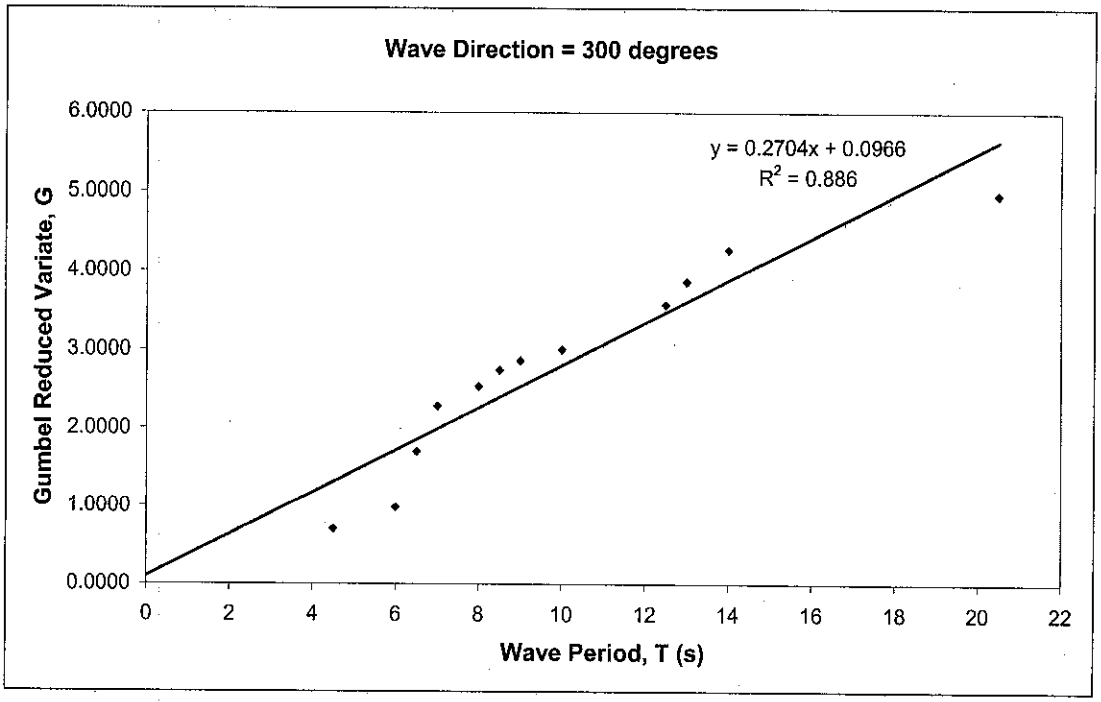


Figure 4.22: Wave period direction at 300°

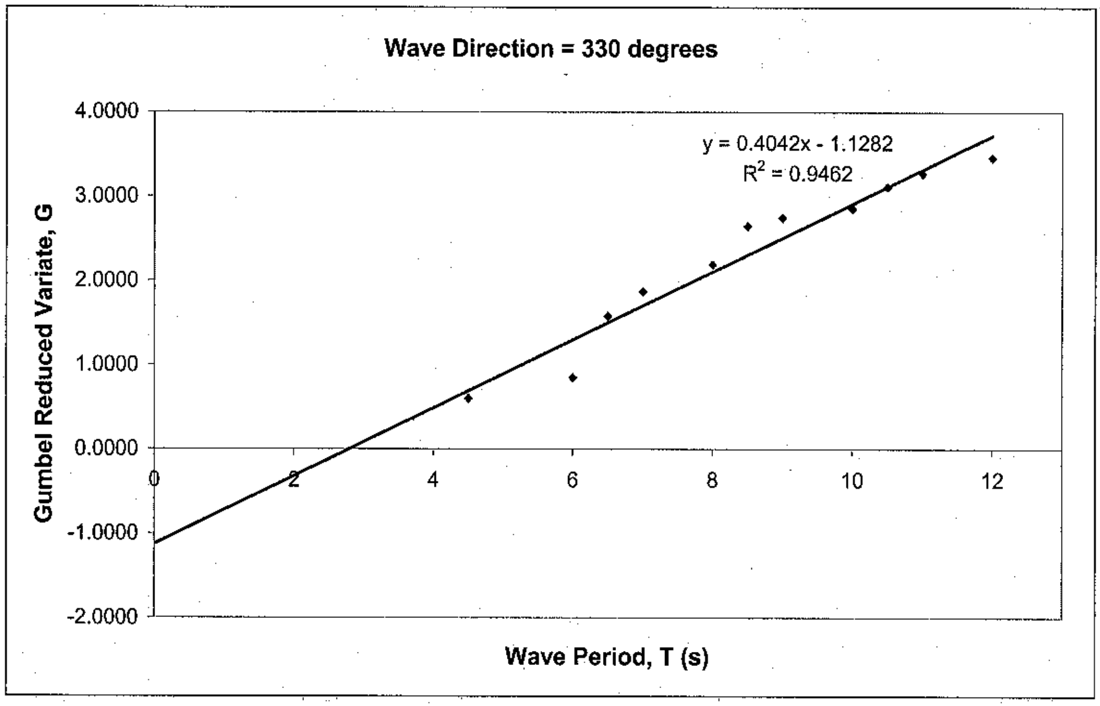


Figure 4.23: Wave period direction at 330°

After the Gumbel Distribution analysis is done on the wave periods for various directions, the predicted wave periods for the various return periods are calculated and tabulated in **Table 4.5**. Data used for this analysis were taken from long term wave observations made during the past 37 years (from 1948 to 1984). Results of the corresponding wave periods are illustrated as **Figure 4.24**. From the summary, the most extreme wave periods occur at the direction of 210° with 23.032 s at the return period of 100 years.

Table 4.5: Corresponding extreme wave periods of various return periods

				Wave Period of Various Return Periods (seconds)					
Wave Direction (Degrees)	λ	β	γ	2 years	5 years	10 years	20 years	50 years	100 years
150°	4.394	2.742	1.259	7.055	9.668	11.600	13.517	16.039	17.942
180°	4.067	3.706	-0.546	6.982	10.526	13.142	15.734	19.144	21.718
210°	3.912	3.915	-0.335	7.455	11.205	13.971	16.710	20.313	23.032
240°	3.807	1.163	3.570	5.850	6.965	7.787	8.601	9.671	10.479
270°	4.294	3.045	1.498	7.860	10.764	12.911	15.040	17.841	19.955
300°	4.500	3.698	-0.357	7.553	11.073	13.679	16.263	19.664	22.232
330°	4.735	2.474	2.791	8.216	10.567	12.309	14.037	16.311	18.029

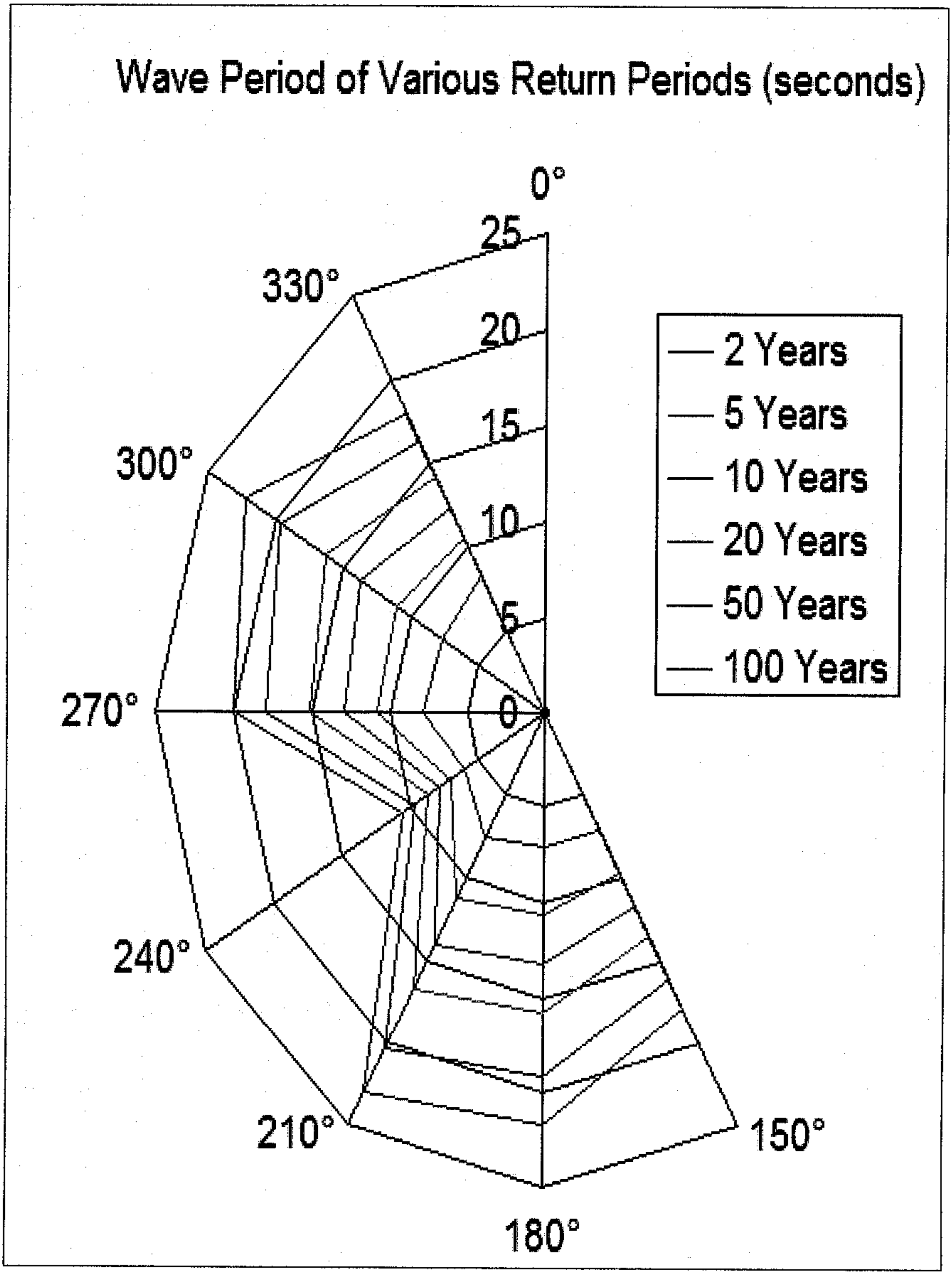


Figure 4.24: Corresponding wave periods of various return periods

The wave climate describe above are those representing the offshore wave conditions. Wave characteristics are expected to change upon entering shallow water. This change in deformation is brought upon from the direct effect of shoaling, refraction, diffraction, etc. The study area at Tanjung Kepah is characterized by very shallow bathymetry. Computer modeling of changes to the wave characteristics in the study area will be performed using the wave data obtained from the Department of Drainage and Irrigation, Malaysia and also the results obtained from the above wave prediction analyses.

CHAPTER 5

NUMERICAL MODELING

5.1 Introduction

The coastal hydrodynamics consist of interaction between the forces of the waves, winds, tides, currents and topographical features. The analyses and determination of the resultant of these forces can be a very difficult and complex task. This is because these interacting forces are very specific and each of them has their own role to be played at the site. Thus, they require fine balance and judgment on the nature and significance of each of the forces. The realization of this difficulty has encouraged the usage of computer modeling as a tool of coastal hydrodynamic studies. Henceforth, the use of modeling is mainly for predictive purposes. As for the case study of this Final Year Project, the hydrodynamics and wave propagation simulation will be carried out for predicting the existing coastal hydrodynamic of Tanjung Kepah. These simulations will be carried by using the professional engineering software package, which is MIKE 21.

5.2 MIKE 21 Nearshore Spectral Wind Wave module (MIKE 21 NSW)

5.2.1 Flow of the MIKE 21 NSW simulations

As shown in **Figure 5.1**, the simulation of the existing coastal hydrodynamic is started off with MIKE 21 Nearshore Spectral Wind Wave (NSW) before proceeds with the setup of MIKE 21 Hydrodynamic (HD). This is because HD model requires output wave radiation stress data from NSW model in order to generate wind-wave induced current. From **Table 4.3**, the dominant wave height is 2.0938 meter at the direction of 300°. With this dominant wave force, the simulation will be conducted in 6 scenarios of various return periods, namely 2 years, 5 years, 10 years, 20 years, 50 years and 100 years.

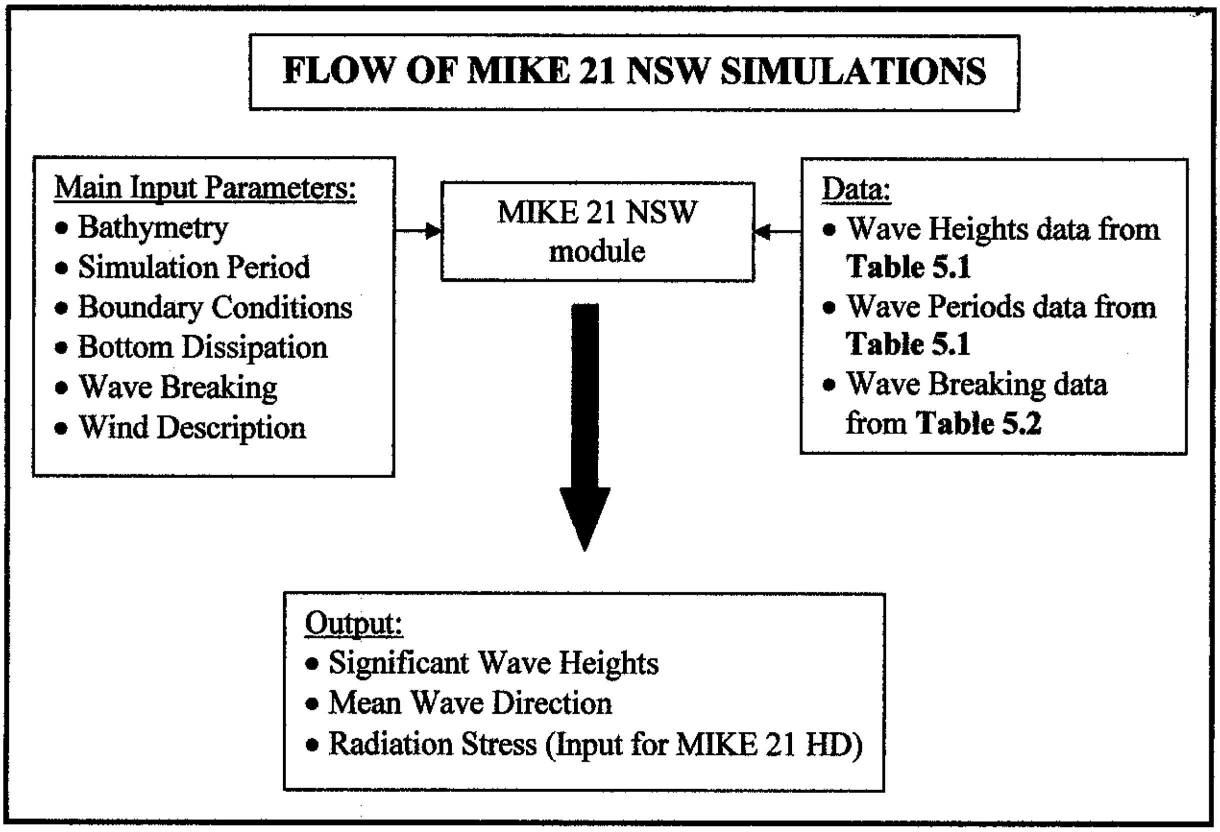


Figure 5.1: Flow of MIKE 21 simulation (MIKE 21 NSW)

5.2.2 Bathymetry

At the beginning stage of modeling, the boundary of the study area must be determined. It is the most important task in the modeling process. It can be done by using the Bathymetry Editor in MIKE Zero tools. Firstly, the working area is defined by setting the coordinate according to the Universal Transverse Mercator Geographic Coordinate System (UTM). Malaysia is located in UTM-47. The positioning of the origin of the bathymetry is at Northing 320,000 meter and Easting 610,000 meter from the central meridian. The size of the boundary area will be covered from Lumut until Pulau Angsa. This is because the boundary conditions are imposed at the location of both Lumut and Pulau Angsa as the tidal stations are located at both areas. Therefore, the size of the bathymetry is set at 200,000 meter by 180,000 meter. The working area is positioned in Northing 320,000 meter and Easting 730,000 meter. It is defined with 121 number of X points and 301 number of Y points. The bathymetry management is tilted by -40° from North to Y orientation. Thus, the bathymetry of the nested bathymetry can be shown in **Figure 5.2.**

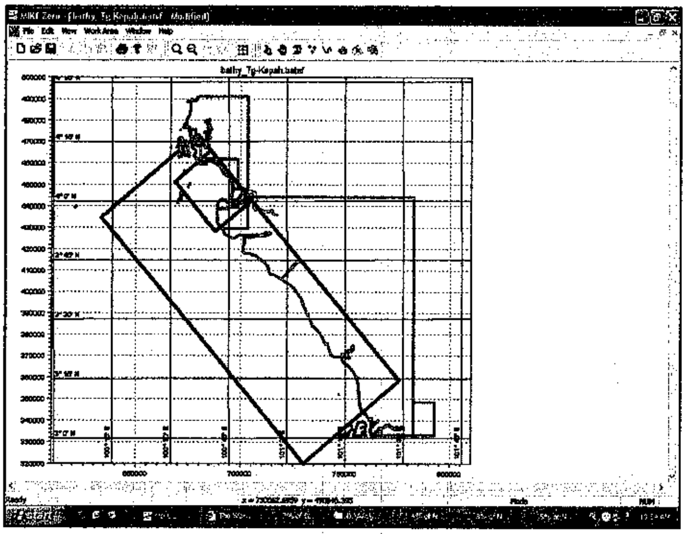


Figure 5.2: Working area of nested bathymetry for 500m and 100m grid spacing

The second step in modeling is constructing the nested bathymetry models with 100 meter resolution. The local nested area is defined by 225 number of X points from the regional area and 301 number of Y points from the regional area. The bathymetry management is tilted by -40° from North to Y orientation. The positioning of the origin of this working area is defined as Northing 428,292.68 meter and Easting 687,822.47 meter.

In this Bathymetry editor, the land values and the water level entry are input as data entry. This data is based mainly on the information from British Admiralty Sea Maps which are digitally extracted from a software product, named C-MAP Norway. This digitized map is obtained from DHI Water and Environment (M) Sdn Bhd as shown in **Figure 5.3.**

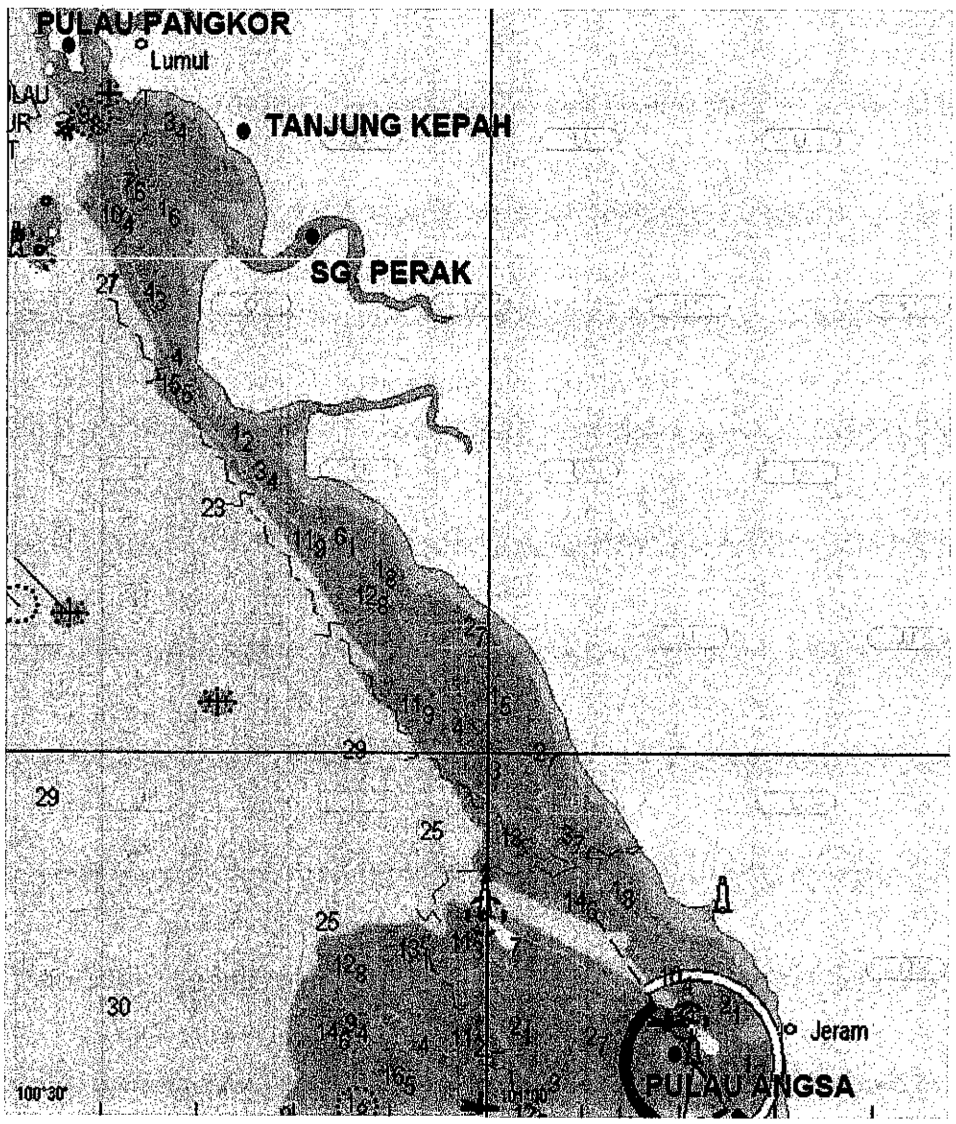


Figure 5.3: Admiralty chart of the regional area

This digitized data will be interpolated and processed by the editor. The bathymetry data in the editor uses ACD (Admiralty Chart Datum) as datum. The 500 meter grid spacing of the bathymetry data can be plotted and shown in **Figure 5.5**. The smaller resolution will be used in the nested Hydrodynamic (HD) module. The advantage of applying the nested grid facility compared to the standard approach of using only one grid is mainly to reduce the computing process speed and also to provide detailed results at the finer grids. The nested bathymetry model of 500 meter grid spacing and 100 meter grid meter spacing is plotted and shown in the **Figure 5.6**. The local nested bathymetry model of 100 meter spacing is generated and shown as in the **Figure 5.4**. Hence, the local nested bathymetry model of 100 meter spacing is taken as the simulation model.

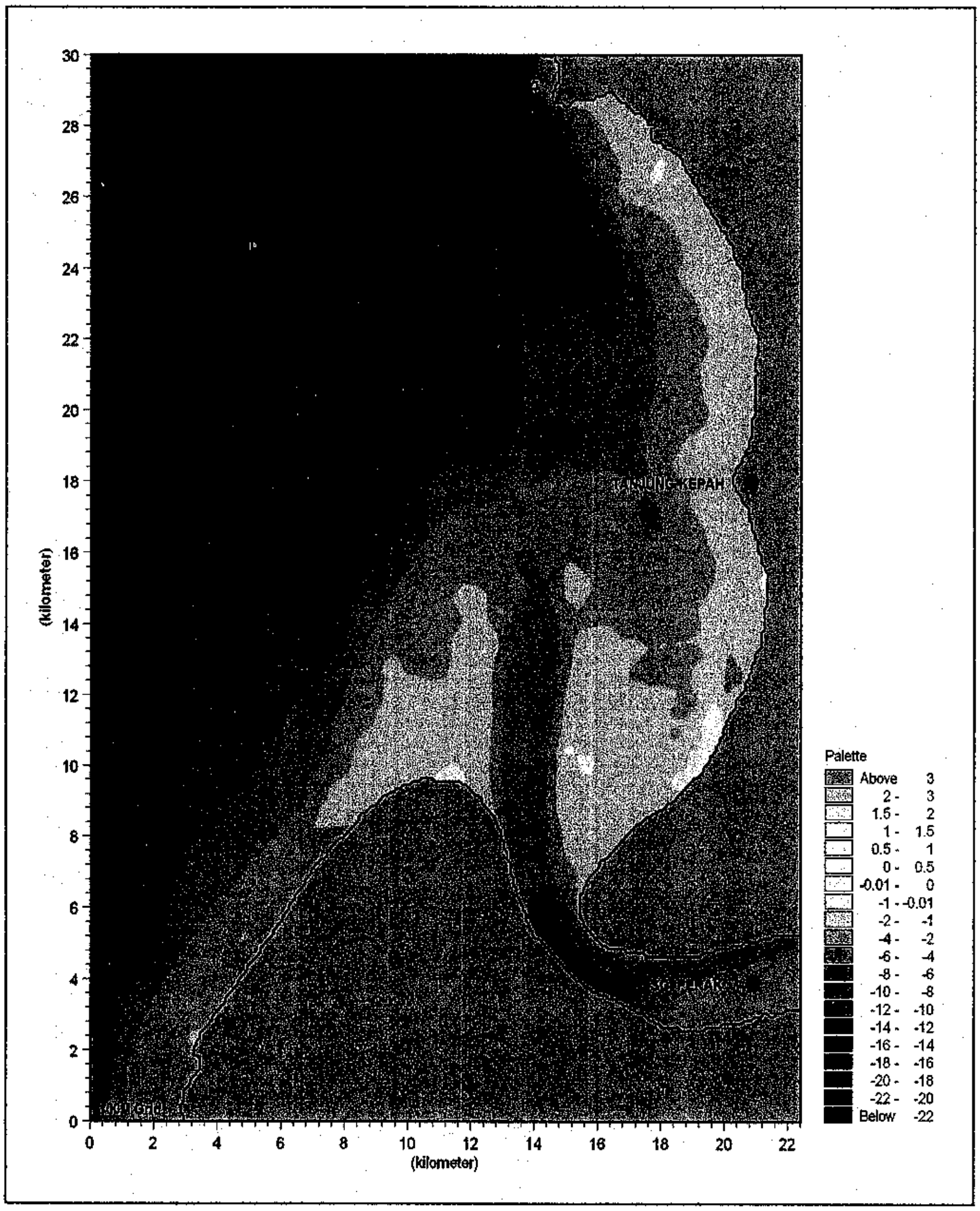


Figure 5.4: Nested model boundary of 100m grid spacing

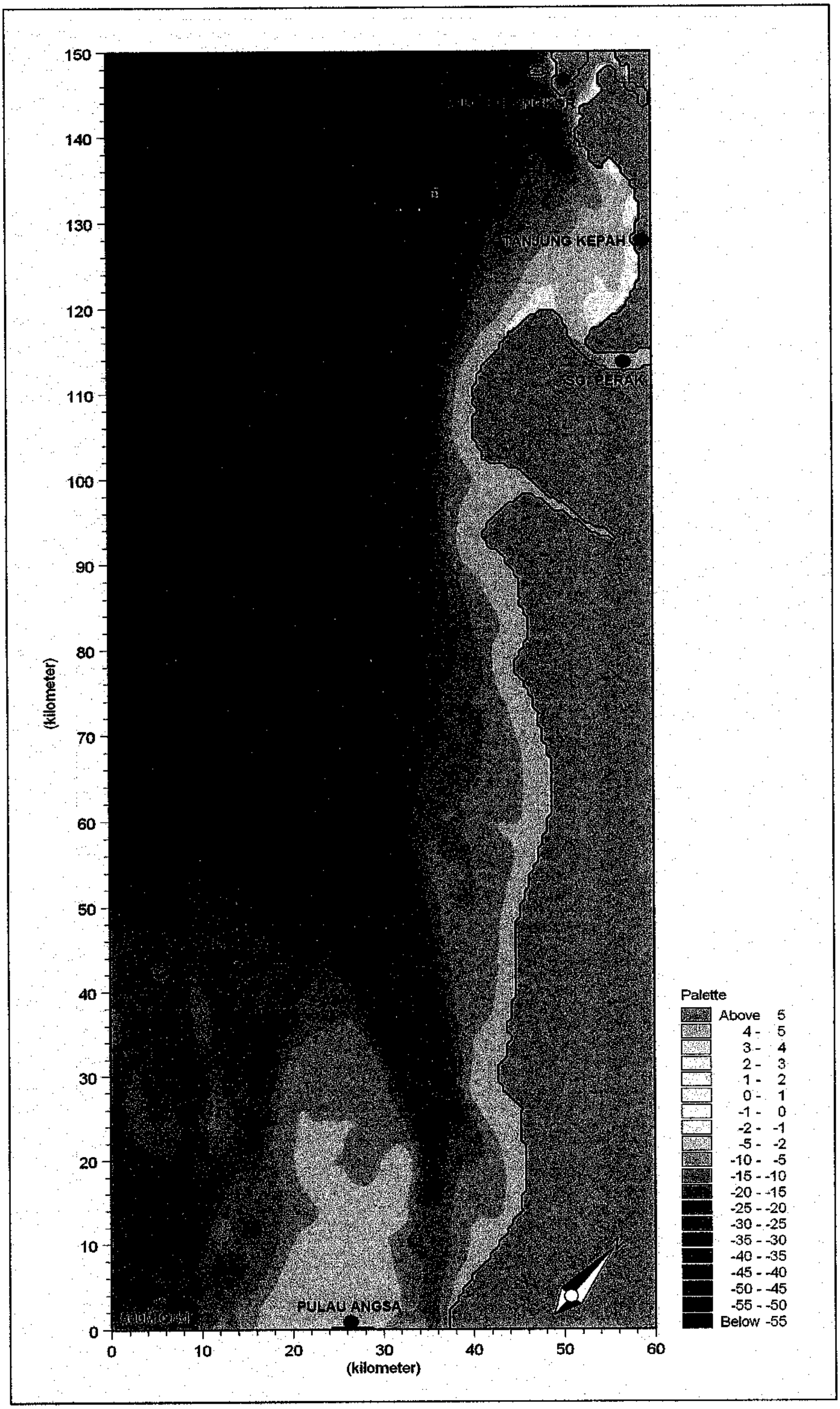


Figure 5.5: Model boundary of 500m grid spacing

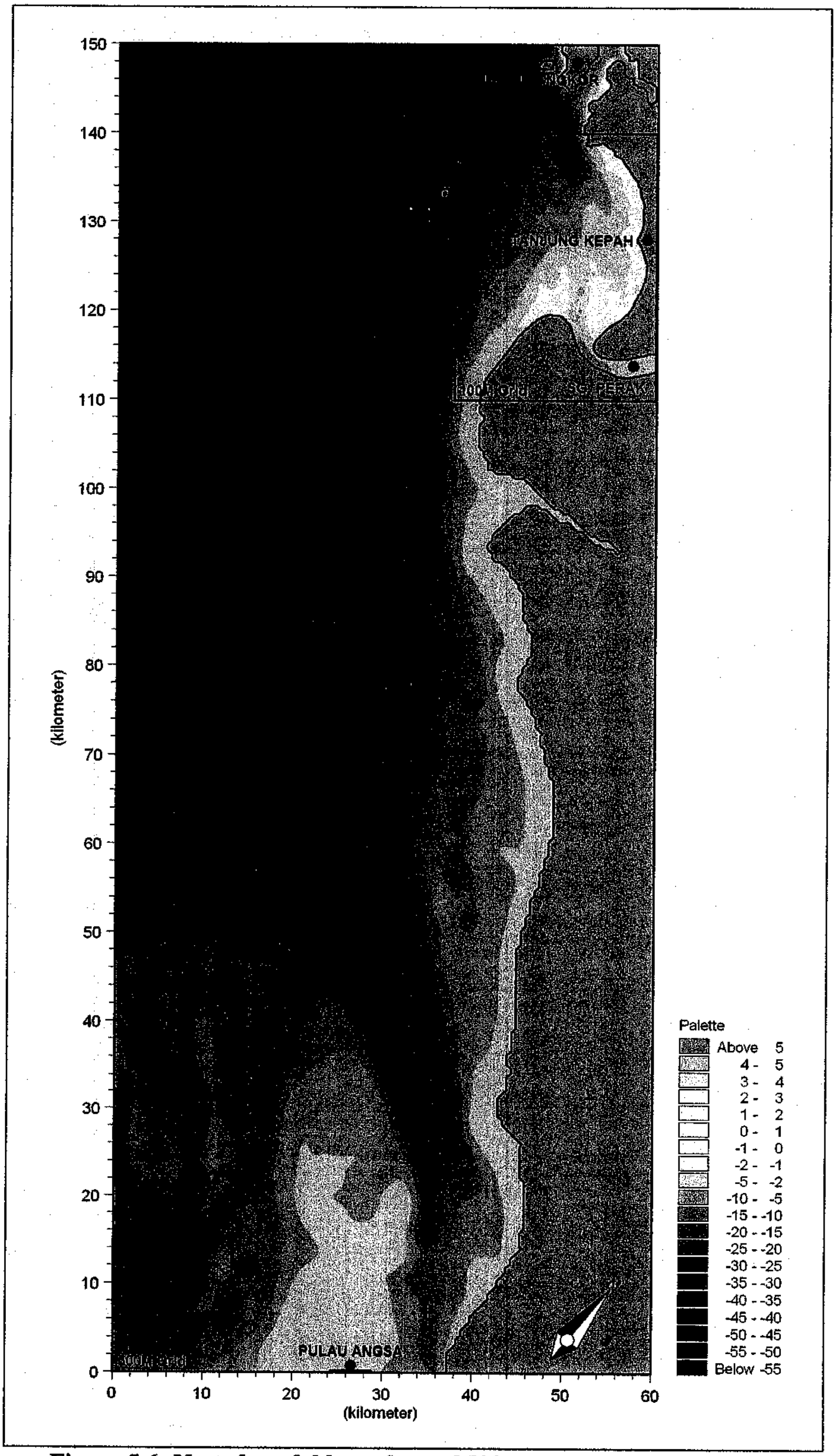


Figure 5.6: Nested model boundary of 500m and 100m grid spacing

5.2.3 Simulation Period

The simulation period is divided into two, which are time description and time values. Time description is defined as quasi-stationary, which means that this model can run in a real time simulation. The number of time steps is set to 121 with 1 hour time step interval. Therefore, the simulation will run for 5 days, start from 20th March 2006 at 12:00pm until 25th March 2006 at 12:00pm in order to cover the spring and neap period. The date is randomly chosen as there is no measured wave and current data from the site. Usually, the simulation period will be set according to the measured data so that calibration and verification of the model can be done.

5.2.4 Boundary Conditions

In the offshore wave conditions, the characteristic of the incoming wave are to be specified as the following parameters:

- Significant wave height, H_{m0}
- Mean wave period, T_m
- Mean wave direction, *MWD*
- Maximum deviation from *MWD*, *MDWD*

From the wave analysis conducted in Section 4.5, the dominant wave angle is set to 300°, which will be the *MWD*. From the Gumbel distribution analysis, the extreme wave heights and wave periods with various return periods for wave approaching at 300° will be taken as the inputs for the H_{m0} and T_m respectively. The data for H_{m0} and T_m are shown in **Table 5.1**. The maximum deviation between the mean direction of wave propagation and the x-axis of the computational grid is approximately 30° at the boundary where the waves enter the model through the offshore boundary.

Table 5.1: Extreme wave heights and wave periods at 300° with various periods

Return Period (years)	Extreme Wave Heights (m)	Extreme Wave Periods (s)
2	2.005	7.553
5	2.569	11.073
10	2.986	13.679
20	3.401	16.263
50	3.946	19.664
100	4.357	22.232

5.2.5 Bottom Dissipation

The model parameters in MIKE 21 NSW include physical input data such as surface elevation, wind and current, as well as parameters controlling the dissipation processes like wave breaking and bottom friction. In the bottom dissipation working sheet, the value of wave friction coefficient or also known as Nikuradse roughness parameter, k_N is determined from the equation 5.1.

$$k_N = 2.5 \times d_{50} \tag{5.1}$$

where d_{50} = Diameter of the particle at 50% finer on the grain size distribution curve (mm)

The information on the grain size at the bed of the near shore is not available and cannot be obtained from the officer from Department of Irrigation and Drainage Malaysia (DID), Manjung. However, with reference to DHI Water and Environment (M) Sdn Bhd it was recommended to use Nikuradse roughness parameter, k_N as 0.08.

The wave breaking parameters are α, γ_1 and γ_2. The parameter α is the rate of energy dissipation after breaking and it is set to be 1.0. The parameter γ_1 is the amount of steepness related breaking and it is set to be 1.5. These values are suggested by the DHI Water and Environment Sdn Bhd. Lastly, the parameter γ_2 controls the amount of depth related breaking and it can be calculated by using an expression for γ_2 by Battjes and Stive (1985).

$$\gamma_2 = 0.5 + 0.4 \times tanh(33 \times S_0) \quad (5.2)$$

Where S_0 = deep water wave steepness

= ratio of deep water root mean square wave height at 300°

and deep water wave length, L_o

The deep water root mean square wave height at 300° is 1.559 meter taken from the **Table 4.3**. The values of γ_2 for various return periods of dominant wave at 300° can be obtained from the following **Table 5.2.**

Table 5.2: Values of γ_2 for various return periods of dominant wave at 300°

Return Period (years)	Extreme Wave Heights (m)	Extreme Wave Periods (s)	$L_O = 1.56T^2$	$S_O = \frac{1.559}{L_O}$	γ_2
2	2.005	7.553	88.99 m	0.01752	0.7085
5	2.569	11.073	191.27 m	0.008151	0.6051
10	2.986	13.679	291.90 m	0.005341	0.5698
20	3.401	16.263	412.60 m	0.003778	0.5496
50	3.946	19.664	603.21 m	0.002585	0.5340
100	4.357	22.232	771.05 m	0.002022	0.5267

5.2.6 Wind Description

The wind speed data is taken from **Appendix 3-12**, Percentage Frequency of Various Directions and Speeds. This wind speed is according to the annual period and the dominant wind is taken to be at 270° with respect to true North. The mean wind speed is calculated by averaging the percentage occurrence of every wind speed as shown below:

$$\bar{v} = \frac{\Sigma(f \times v)}{\Sigma f} \quad (5.3)$$

Where v = wind speed

f = frequency of occurrence

Thus, the mean wind speed is approximately 3 m/s. The wind-wave generation is the process by which the wind transfers energy into the water body for generating waves. The formulation of the wave generation by wind is based on JONSWAP expression.

5.2.7 Output

Two types of output data can be obtained from the MIKE 21 NSW simulations. These are:

- Significant wave heights, wave period and directions
- Wave radiation stresses

The first result is used in the 2D plots to show the characteristic and effects of the waves at the study area. These results can be referred to **Appendix 4.1** which will be a data file in CD format. The second output is a data file, which is wave radiation stresses. It will be used in the MIKE 21 Hydrodynamic (HD) model to generate the wind-wave induced current results.

5.3 MIKE 21 Hydrodynamic (MIKE 21 HD)

MIKE 21 HD model is used to simulate the existing coastal hydrodynamic with the addition of wave radiation stress. This is to produce wind-wave induced current. The flow of MIKE 21 HD simulations is shown in **Figure 5.7**.

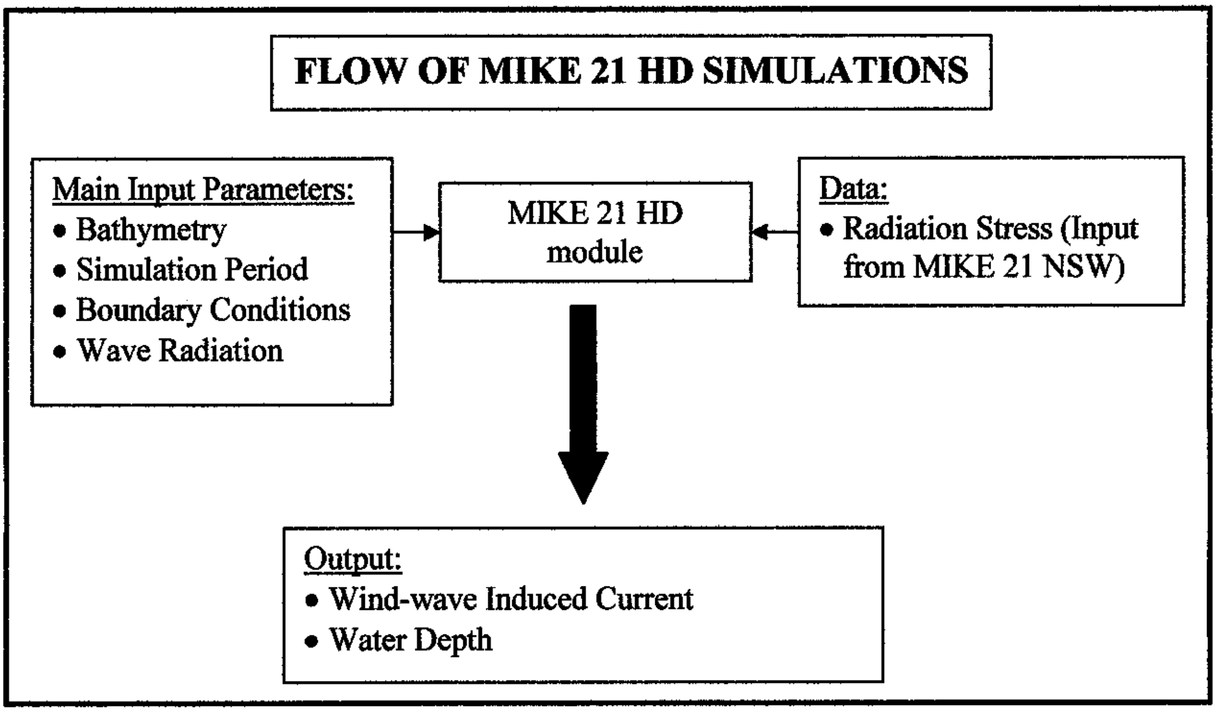


Figure 5.7: Flow of MIKE 21 simulation (MIKE 21 HD)

5.3.1 Bathymetry

The bathymetries used in the MIKE 21 HD models are similar to the ones used in MIKE 21 NSW models. The bathymetry model is the 100 meter spacing grid as shown in **Figure 5.4**.

5.3.2 Simulation Period

The simulation period for MIKE 21 HD will also be the same as the inputs set in the MIKE 21 NSW. This is because the wave radiation stress data file will be input into this MIKE 21 HD. Thus, the simulation period is 5 days, start from 20th March 2006 at 12:00pm until 25th March 2006 at 12:00pm. The time step interval is 1 hour.

5.3.3 Boundary Conditions

The northern boundary of the regional bathymetry model is defined by the Lumu Pier tidal elevation time series while the southern boundary of the regional model is defined by the Pulau Angsa tidal elevation time series. Each cell in the water region will be defined and interpolated from both boundaries in the 500 meter grid regional model.

The boundary conditions for the 100 meter grid spacing or local nested model are transferred from the boundary conditions in the 500 meter grid spacing regional model.

5.3.4 Wave Radiation

The input data for the wave radiation stress is obtained from output data file from the simulation of MIKE 21 NSW previously. With this data, the MIKE 21 HD is able to generate wind-wave induced current in the numerical modeling.

5.3.5 Output

MIKE 21 HD will produce 2 types of outputs. The first result is used in a 2D plot to show the characteristic and effects of the water depth at the study area. These results can be referred to **Appendix 4.2** which will be a data file in CD format. The second output is also a 2D plot to show the characteristic and effects of the wind-wave induced current at the study area. These results can also be referred to **Appendix 4.3** which will be a data file in CD format.

CHAPTER 6

RESULTS AND DISCUSSIONS

6.1 Introduction

The numerical modeling of Tanjung Kepah has been conducted to simulate existing hydraulic processes. Subsequently, the simulated results for wave distribution and current flow are tabulated and interpreted accordingly in section 6.2 and 6.3.

6.2 Results

The data of significant wave heights and wave directions, water depth measured from the mean sea level and wind-wave induced current speed are extracted from the images taken from the results generated by the simulation of MIKE 21 NSW and MIKE 21 HD. The extracted data is taken from 10 stations located in the vicinity of Tanjung Kepah during spring tides and neap tides. The locations of the 10 stations can be shown in **Figure 6.1**. The grid coordinate of each station and its radial distance from Tanjung Kepah can be tabulated in **Table 6.1**.

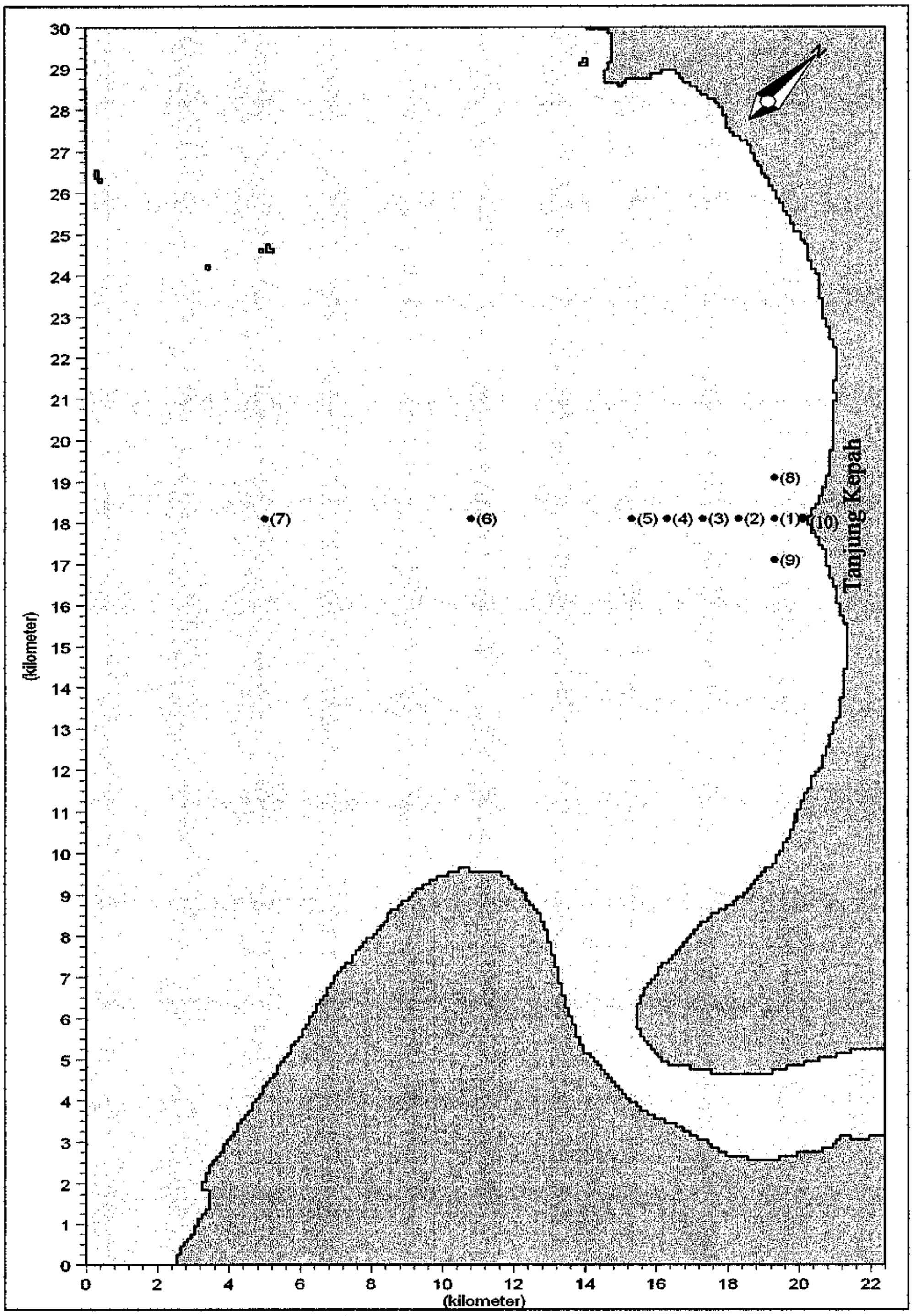
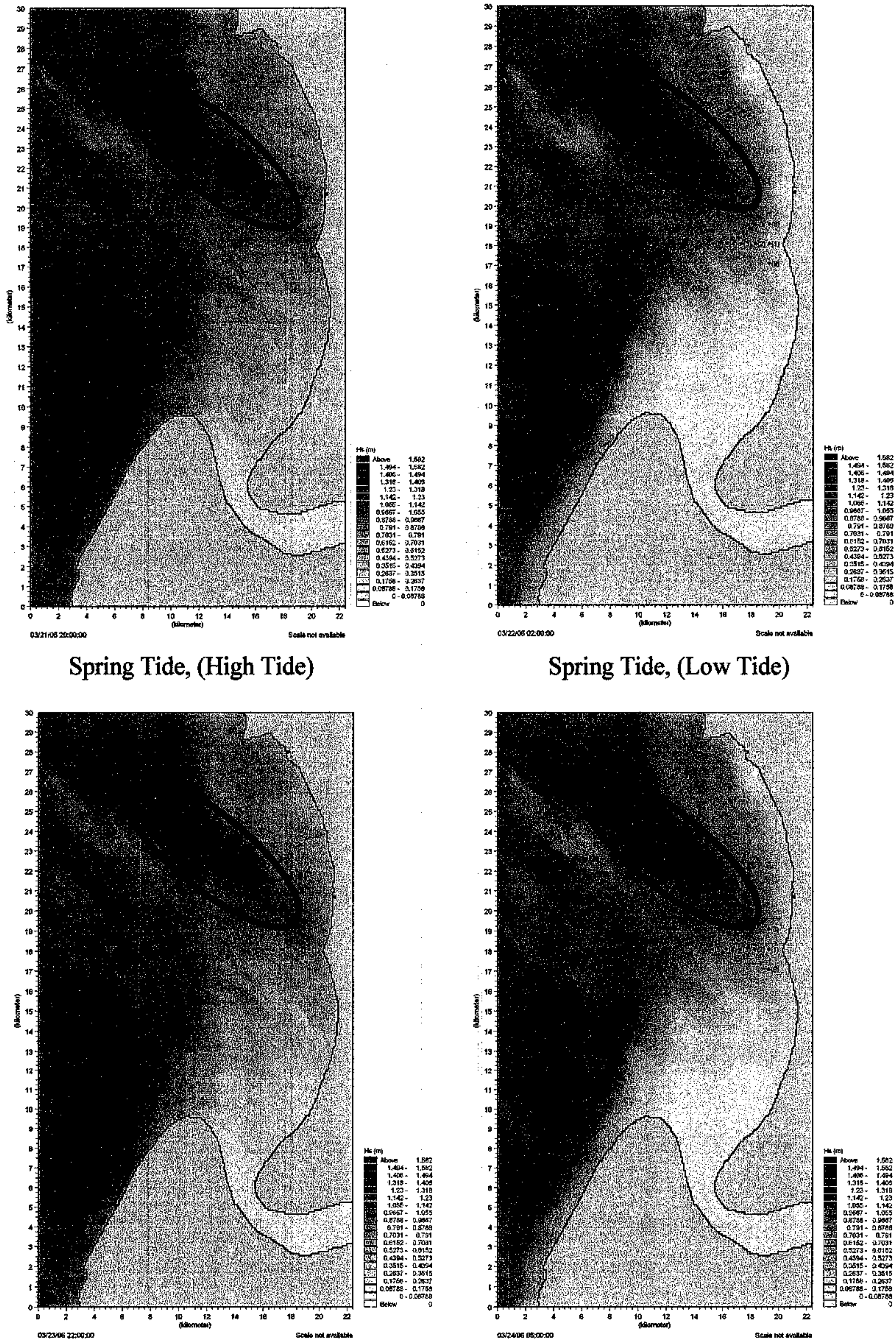


Figure 6.1: Location of 10 stations

Table 6.1: Location of the 9 stations

Station	Grid Coordinate	Distance From Tanjung Kepah, x (km)
1	(193,181)	1
2	(183,181)	2
3	(173,181)	3
4	(163,181)	4
5	(153,181)	5
6	(108,181)	9.5
7	(50,181)	15.3
8	(193,181)	1.414
9	(193,171)	1.414
10	(202,181)	0.1

At every station, wave heights and wind-wave induced current speeds and directions during spring high tide, spring low tide, neap high tide and neap low tide are extracted from simulated results. These simulated results are images generated by MIKE 21 NSW and MIKE 21 HD, which can be referred to **Appendix 4.1**, **Appendix 4.2** and **Appendix 4.3**. Therefore, the wave heights and wind-wave induced current data are recorded and tabulated in **Appendix 5.1**. For example, the images in **Figure 6.2** are the 2D flow of simulated wave heights with return period of 50 years occur during the spring high tide, spring low tide, neap high tide and neap low tide. Therefore, wave heights at every station are observed and recorded. After that, same steps are repeated for **Figure 6.3** to record the data for wind-wave induced current speeds and directions with return period of 50 years.



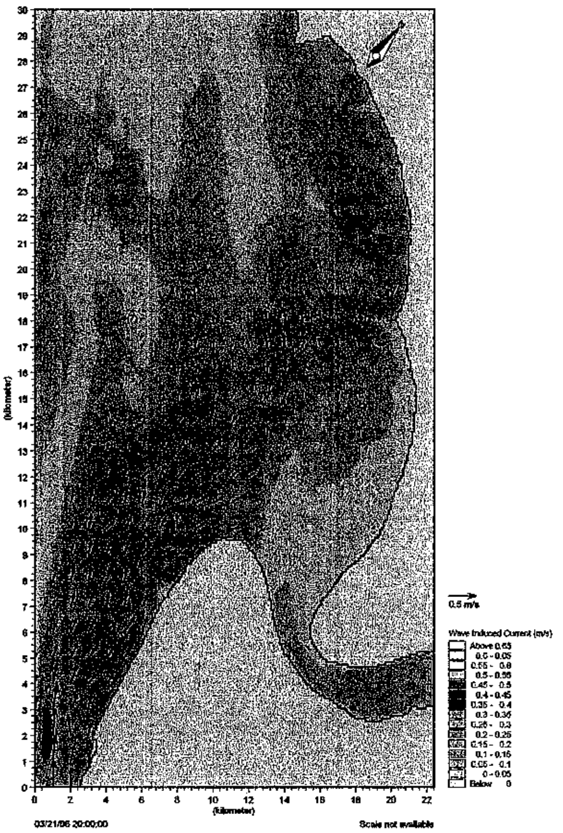
Spring Tide, (High Tide)

Spring Tide, (Low Tide)

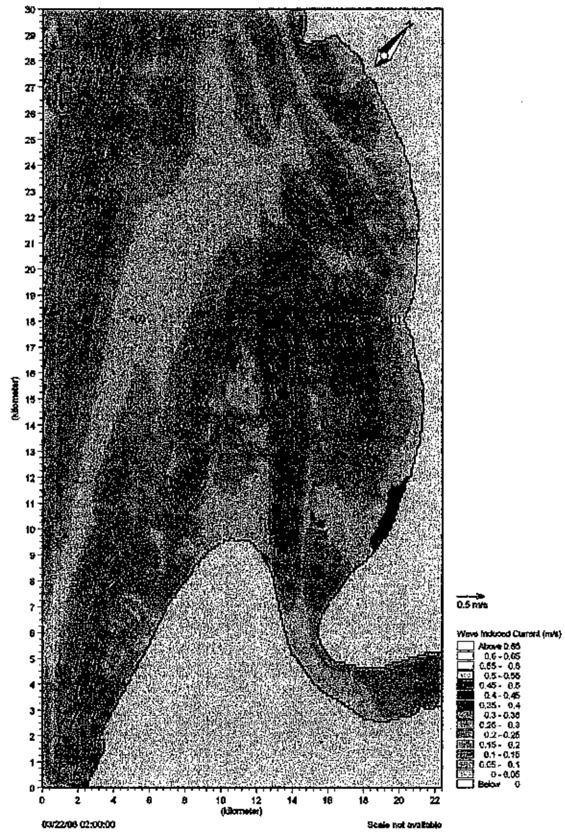
Neap Tide, (High Tide)

Neap Tide, (Low Tide)

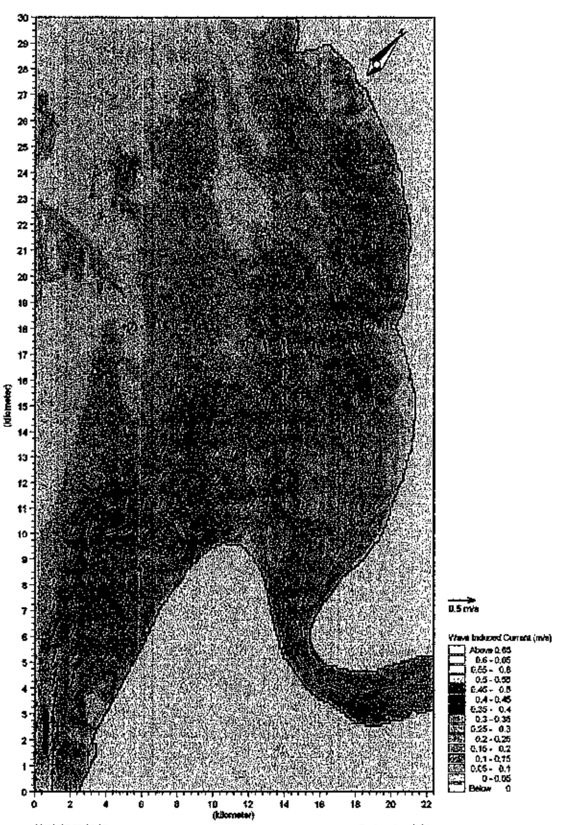
Figure 6.2: Simulated wave height during 50 years of return period



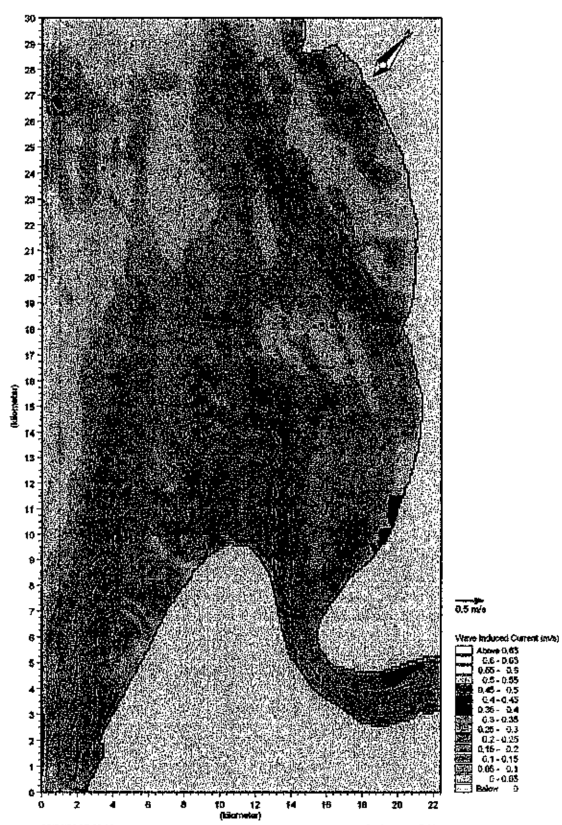
Spring Tide, (High Tide)



Spring Tide, (Low Tide)



Neap Tide, (High Tide)



Neap Tide, (Low Tide)

Figure 6.3: Simulated wind-wave induced current during 50 years of return period

6.2 Discussions of Simulated Results

6.2.1 Wave Analysis

Incoming waves are attenuated by the two islands, namely Pulau Agas and Pulau Payong as shown in the **Figure 6.2.** In this figure, the area behind the two islands has lighter blue color, which means the wave heights are lower as compared to the incoming waves. This also shows that the islands act as breakwaters and wave diffraction occurs at these areas. Wave energy is laterally transferred along the wave crest as the wave bend around the islands. As the wave crest passes the tip of the islands, wave crests bend and spread the wave energy in the lee of the island. Wave refraction can be analyzed from **Figure 6.2.** This can be done by studying the contour of the sea bed at 100 meter grid spacing, which can be referred to **Figure 5.4**. From **Figure 6.2**, waves are concentrated towards the Tanjung Kepah shore as indicated in the red circle because Tanjung Kepah is a headland as shown in the bathymetry map and also the contours play a role for the wave refraction. This causes wave energy to be concentrated towards the headland during the spring tide and neap tide. Waves are diverged when they are approaching the bays, thus wave energy is spread out causing less damage to the shoreline and deposition of beach materials may occur at the shore. In the wave refraction analysis, the wave characteristics at the headland show greater wave heights than the wave characteristics at the bay.

Wave analysis has been carried out to study the behavior of the incoming waves towards the Tanjung Kepah beach. This analysis can be carried out after the extraction of the wave heights data from the **Appendix 5.1**. From this data, wave height (during spring high tide, spring low tide, neap high tide and neap low tide) can be plotted against various return periods (2 years, 5 years, 10 years, 20 years, 50 years and 100 years) in the following from **Figures 6.4** until **Figure 6.12**. These relationships will show the reaction of the waves in various return periods and also in different locations away from the Tanjung Kepah shore.

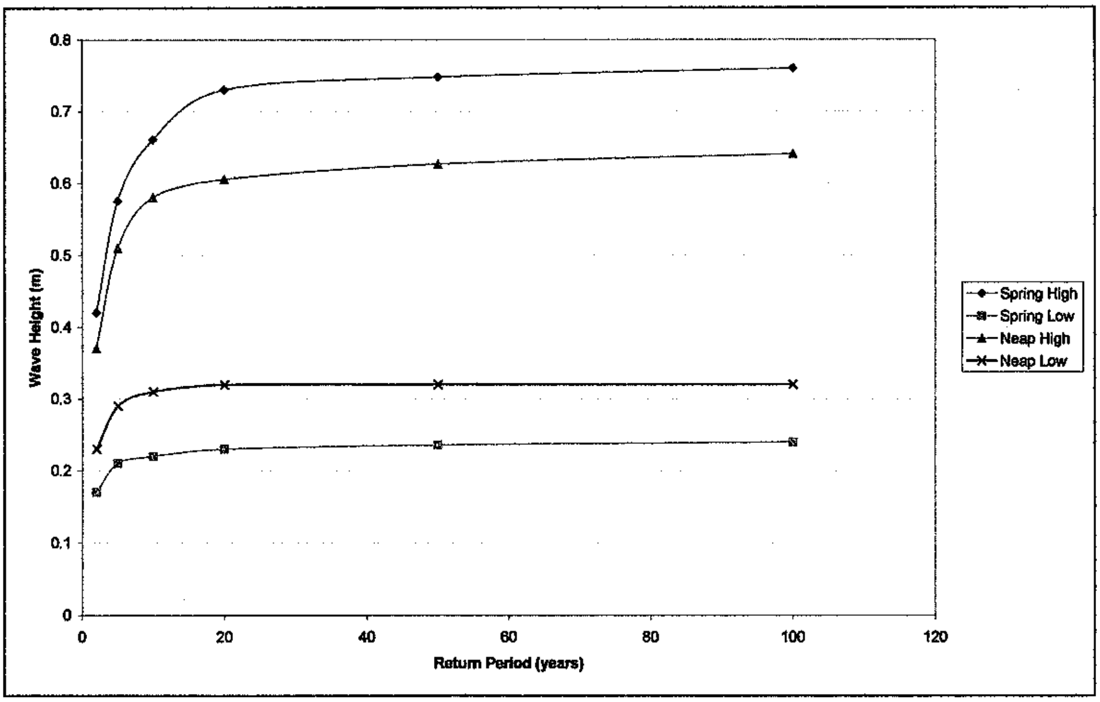


Figure 6.4: Wave height against various return periods at Station 1

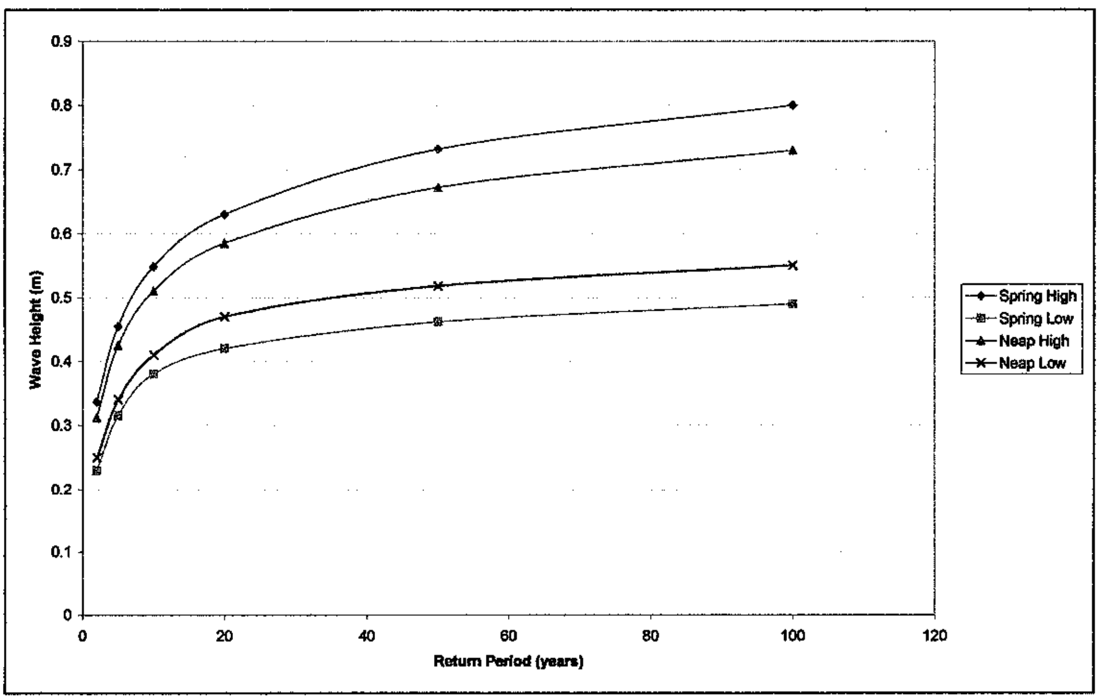


Figure 6.5: Wave height against various return periods at Station 2

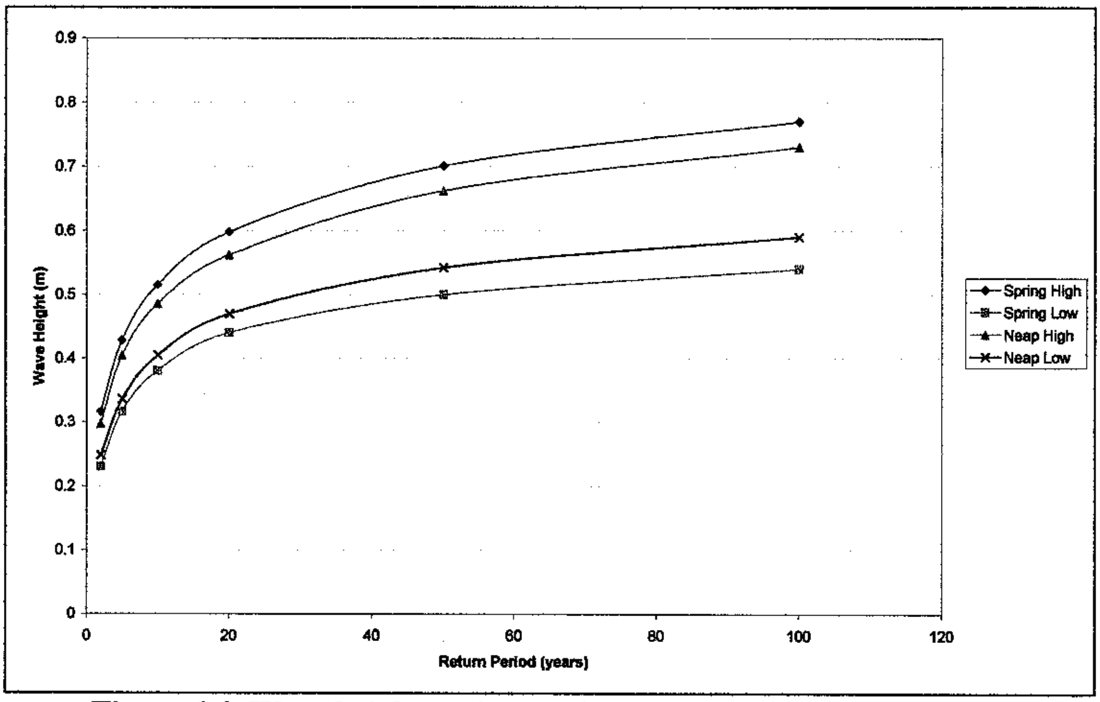


Figure 6.6: Wave height against various return periods at Station 3

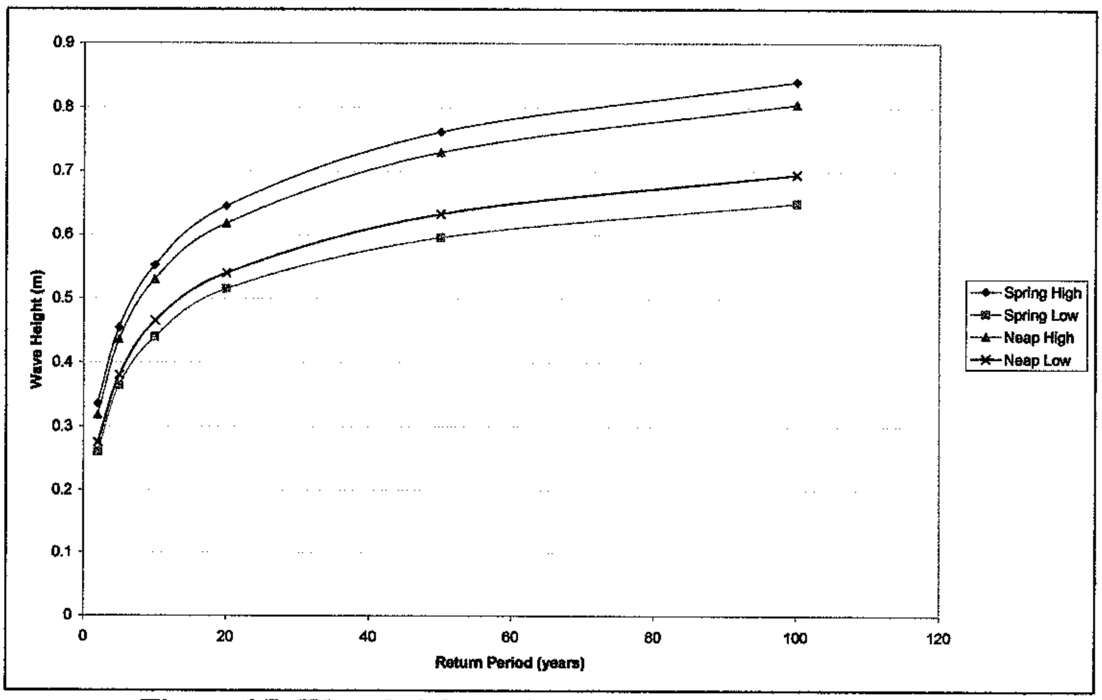


Figure 6.7: Wave height against various periods at Station 4

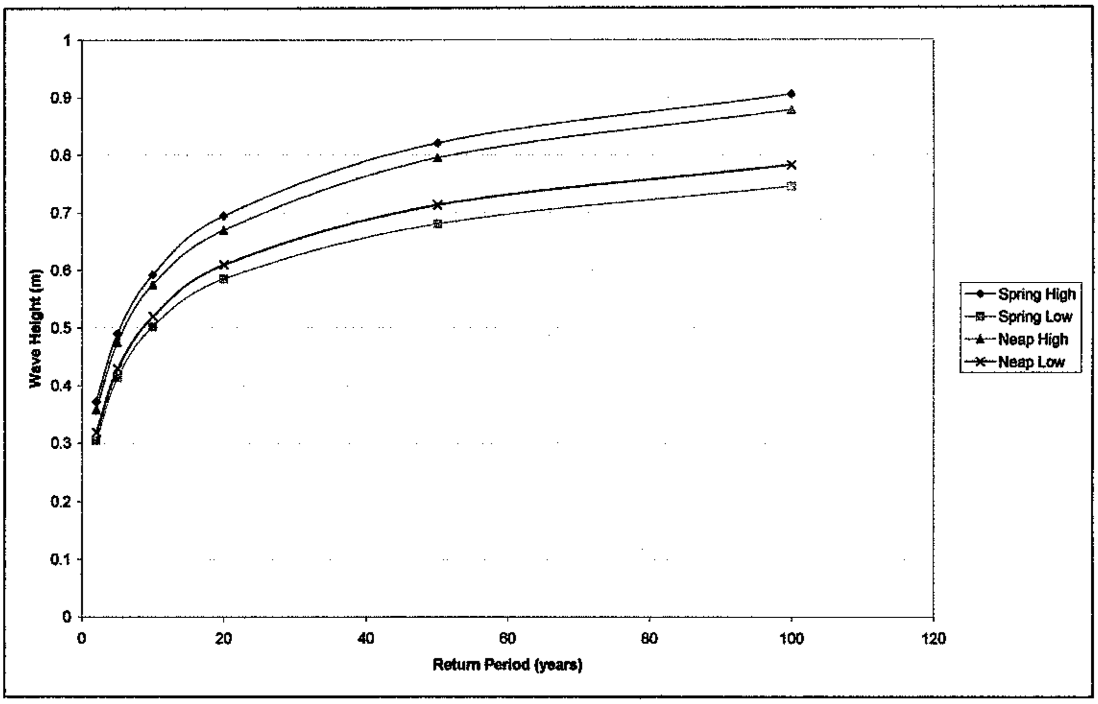


Figure 6.8: Wave height against various periods at Station 5

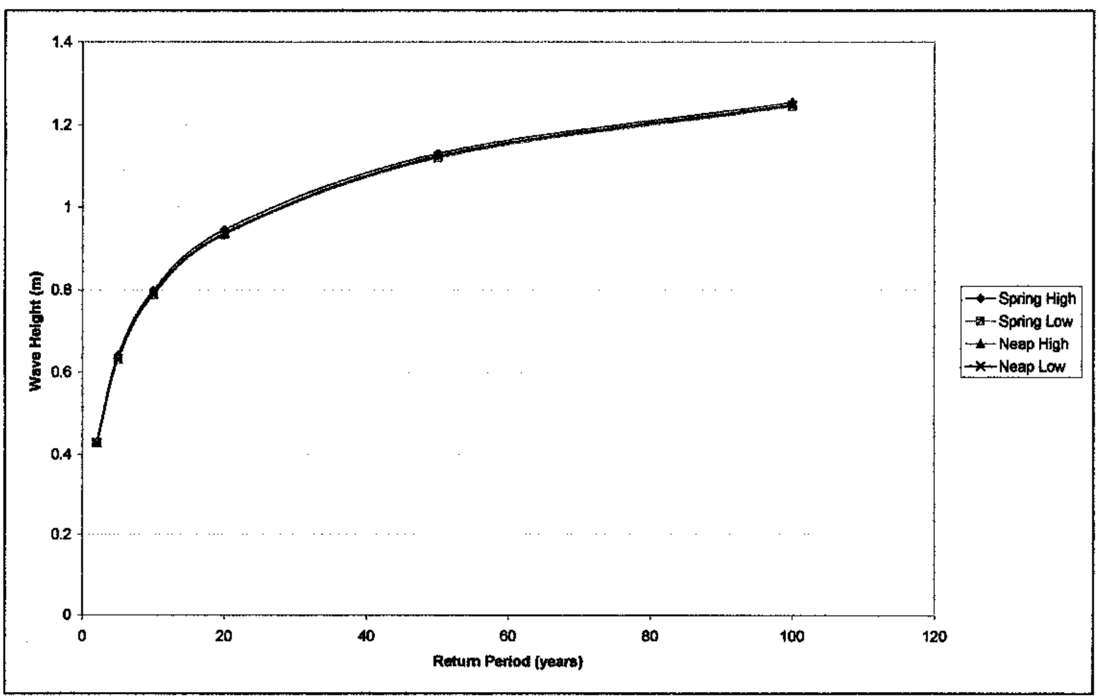


Figure 6.9: Wave height against various periods at Station 6

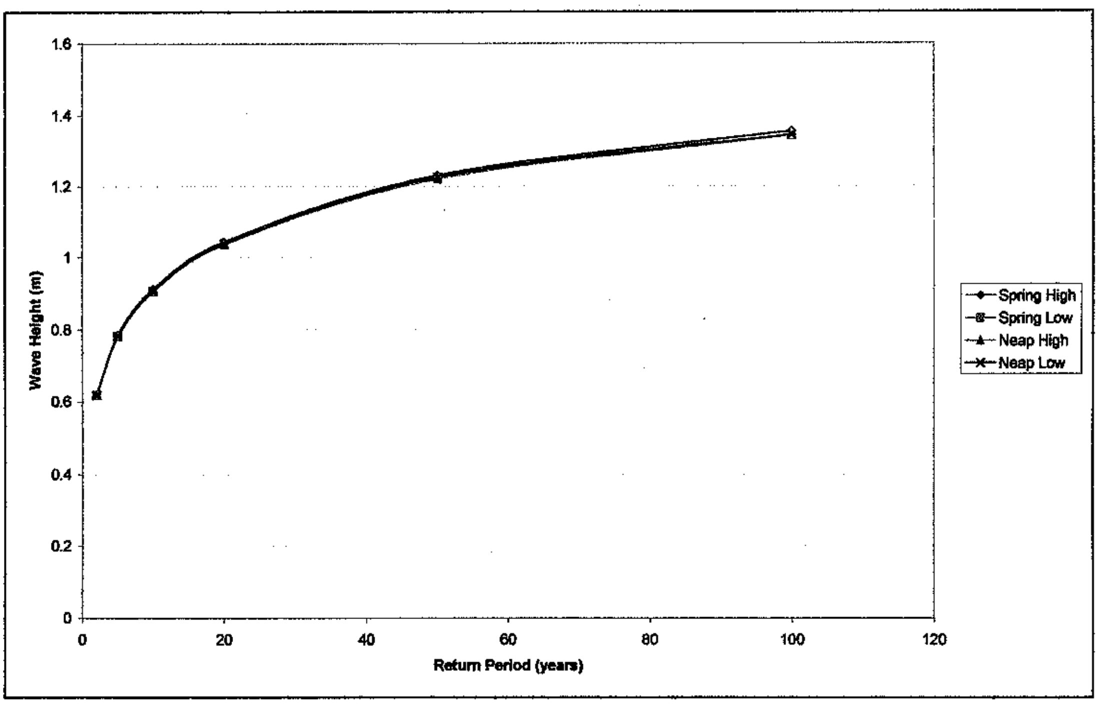


Figure 6.10: Wave height against various periods at Station 7

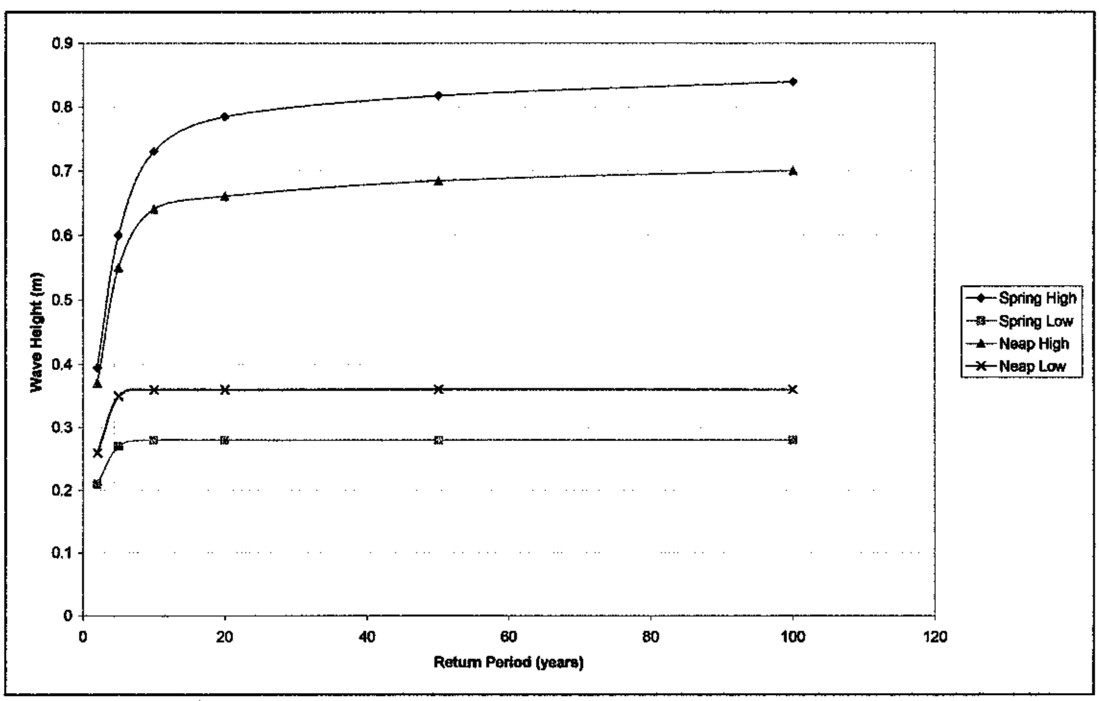


Figure 6.11: Wave height against various periods at Station 8

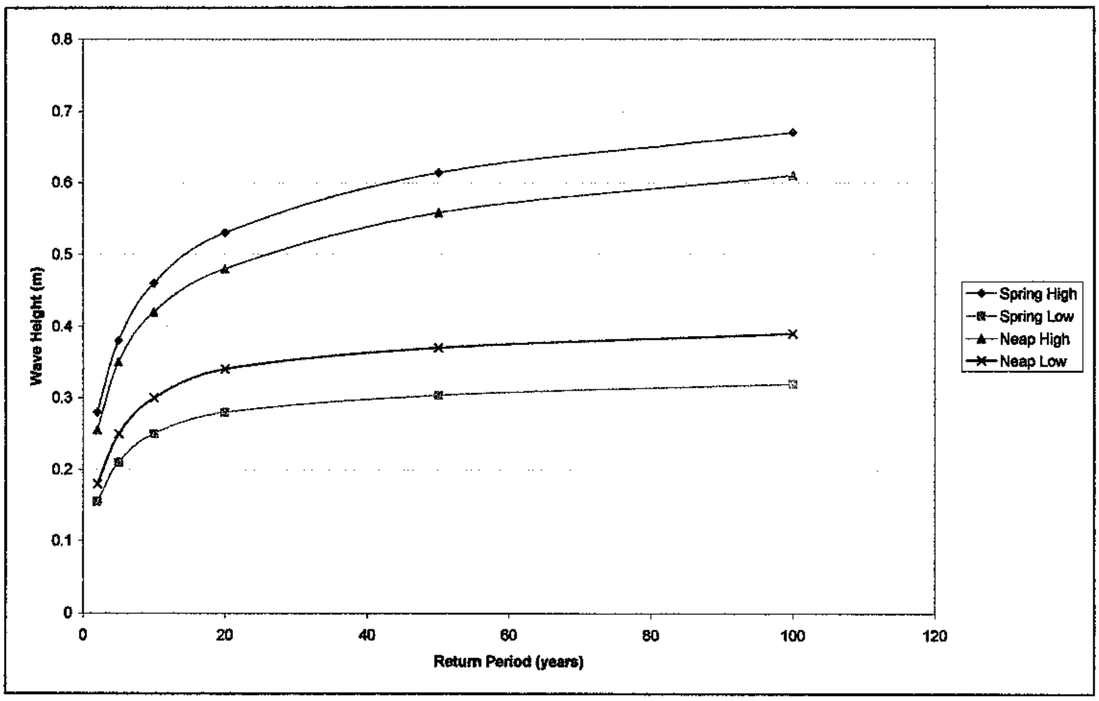


Figure 6.12: Wave height against various periods at Station 9

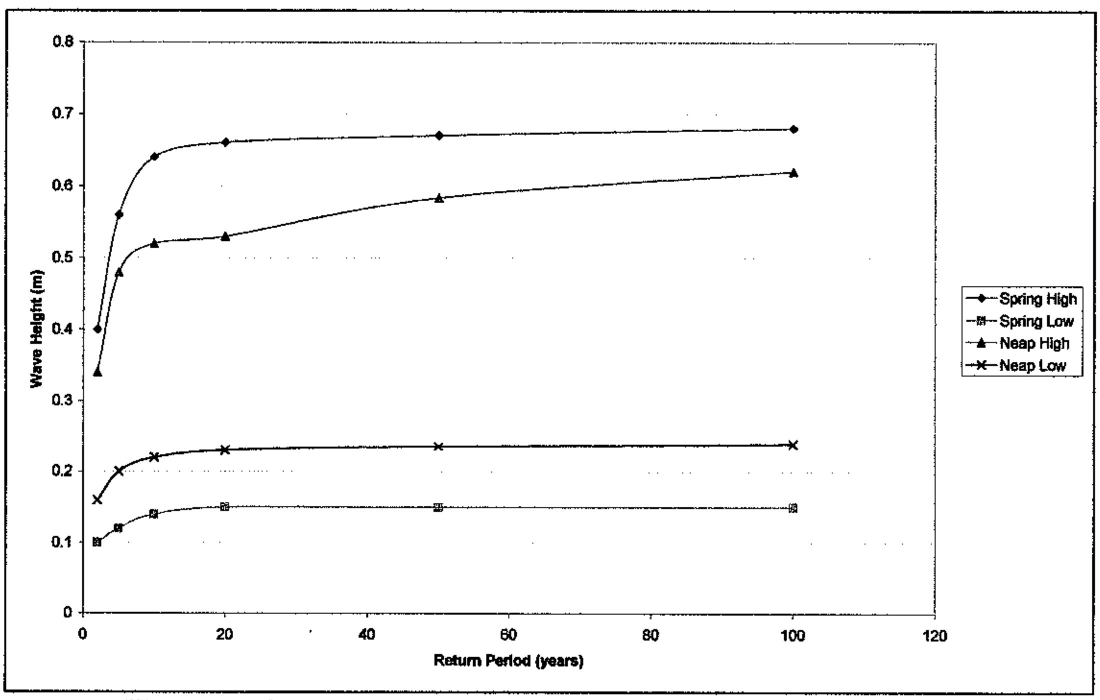


Figure 6.13: Wave height against various periods at Station 10

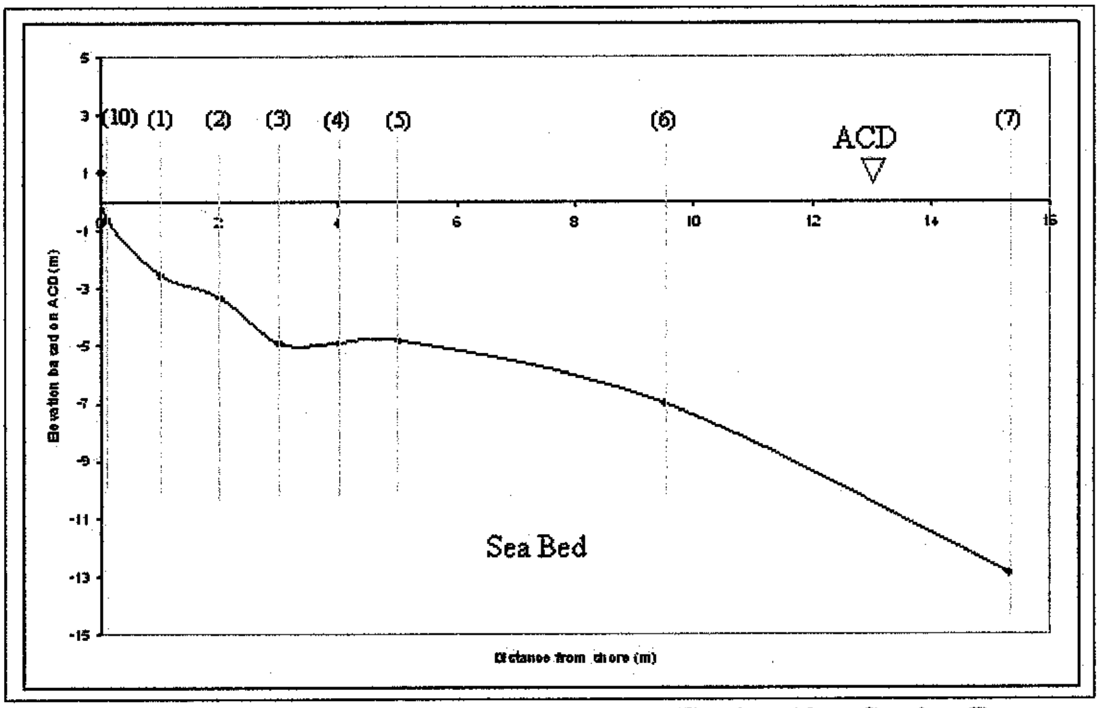


Figure 6.14: Cross section of bathymetry (Station 10 to Station 7)

As shown from **Figure 6.4** to **Figure 6.14**, the wave heights are decreasing from station 7 to station 10 as the trains of wave are approaching the Tanjung Kepah shore. This is because the deepwater waves begin to 'feel bottom' as they begin to enter transitional water. The waves are slowed, shortened and steepened as they are approaching from deeper water into more transitional water. This effect is called shoaling effect. Besides that, there are near-shore wave breakers in the surf zone as the deepwater wave approaching the transitional water. The wave energy and height is reduced due to limited water depth. This is because the cycloid motion reaches the bottom and it becomes disorganized, thus it disturbs the bed sediments. This underwater friction and turbulence at the bottom slows the wave and shortens wavelength, causing the wave to become steeper as wave height increases. Wave breakers disturb the bottom, erode and transport the sediments towards the shore. This justifies the movement of waves with the numerical modeling as the waves travel from deepwater to shallow water.

During the spring high tide, the wave heights are higher than the wave heights occur during the neap high tide. These are shown by **Figure 6.4** to **Figure 6.13**. But, the wave heights during the spring low tide are lower than the wave heights occur during the neap low tide. These results show that the numerical modeling provides as accurate results as possible at the Tanjung Kepah site. Although, there are no measured data to be compared with as there is lack of information obtained from the site and authorities. Even though **Figure 6.9** and **Figure 6.10** show a cluster of lines, both of the figures have the same trend as other figures of wave height against various periods. Theoretically, the fluctuations of the tidal waves at station 6 and 7 are hard to be observed and insignificant. This is due to the high water depth at station 6 and 7, which are 7 meter and 13 meter below ACD respectively. Hence, the wave heights at station 6 and station 7 at 50 years are 1.23 meter and 1.13 meter above ACD respectively.

From **Figure 6.8**, the wave height at station 5 during the spring high tide at 50 years is 0.82 meter above ACD and wave height at station 4 is 0.76 meter above ACD as shown in **Figure 6.7**. There is a decreased of the wave heights as the train of waves move from station 6 to 5. This is because the water depths reduced from 7 meters to 5 meters below ACD. The waves are moving up the steeper bed slope from station 3 to station 1. Hence, this upslope will cause the shoaling effect to be greater. At 50 years during the spring high tide, the wave height at station 3 is 0.70 meter above ACD, wave height at station 2 is 0.73 meter above ACD and wave height at station 1 is 0.75 above ACD. Wave heights increase as the waves are approaching the shore and moving up the bed slope. At station 10, the wave height during the spring high tide at 50 years is 0.70 meter above ACD. This shows that the wave decreases when the waves enter from transitional water into shallow water. Some energy loss occurs when waves refract and break at the shallow water.

In **Figure 6.15**, the bed slope is flat horizontally with overall water depth of 2.5 meter below ACD. At station 8, the wave height during the spring high tide at 50 years is 0.82 meter above ACD. At station 9, the wave height during the spring high tide at 50 years is 0.61 meter above ACD. At station 1, the wave height during the spring high at 50 years is 0.75 meter above ACD. These show that the waves are refracting from station 8 towards station 9 according to the bathymetry of the bed.

This can be said that waves are concentrating at the headland which is Tanjung Kepah.

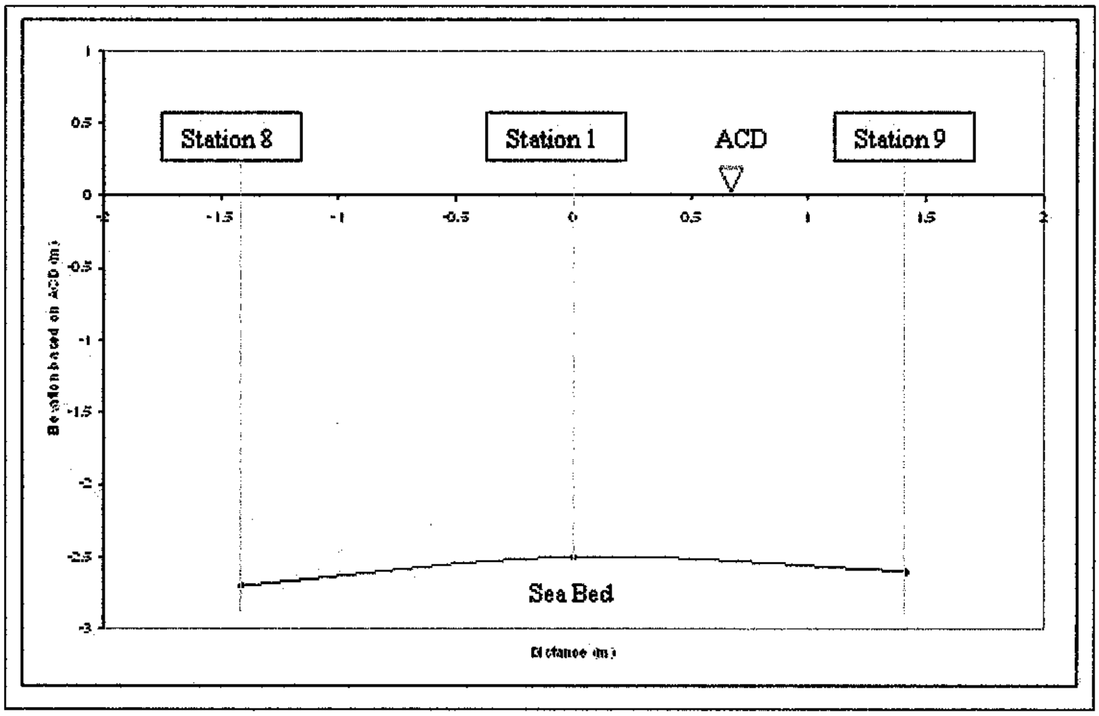


Figure 6.15: Cross section of bathymetry (Station 8, 1 and 9)

6.2.2 Current Analysis

Current analysis has been carried out to study the current activities at the near shore zone of Tanjung Kepah hydrodynamic regime. From **Figure 6.3**, current is flowing strongly at the bottom boundary of the model during spring high tide. This may due to the topography of the seabed where the water depth is high and has less bed resistance. During the spring low tide, we can observe that the current flow pattern is strong at the top edge of the model. This may due to the current is preferably flowing at the area where the bed resistance is low. There is a current circulation occurs at the tip of the river mouth. This is because the velocity of the river flow is higher and may cause this current circulation. During the neap high tide, the current flow pattern is nearly the same as in the spring high tide. In the neap low tide, the current is flowing into the river channel and there is a current circulation at the tip of the river mouth.

This current analysis can also be carried after the extraction of the wind-wave induced current data from the **Appendix 4.2**. The extracted data will then be recorded and tabulated in **Appendix 5.1**. From this data, current speeds with current directions (during spring high tide, spring low tide, neap high tide and neap low tide) can be plotted against various return periods (2 years, 5 years, 10 years, 20 years, 50 years and 100 years) in the following from **Figures 6.16** until **Figure 6.25**. These relationships will show the activities of the currents in various return periods and also in different locations away from the Tanjung Kepah shore.

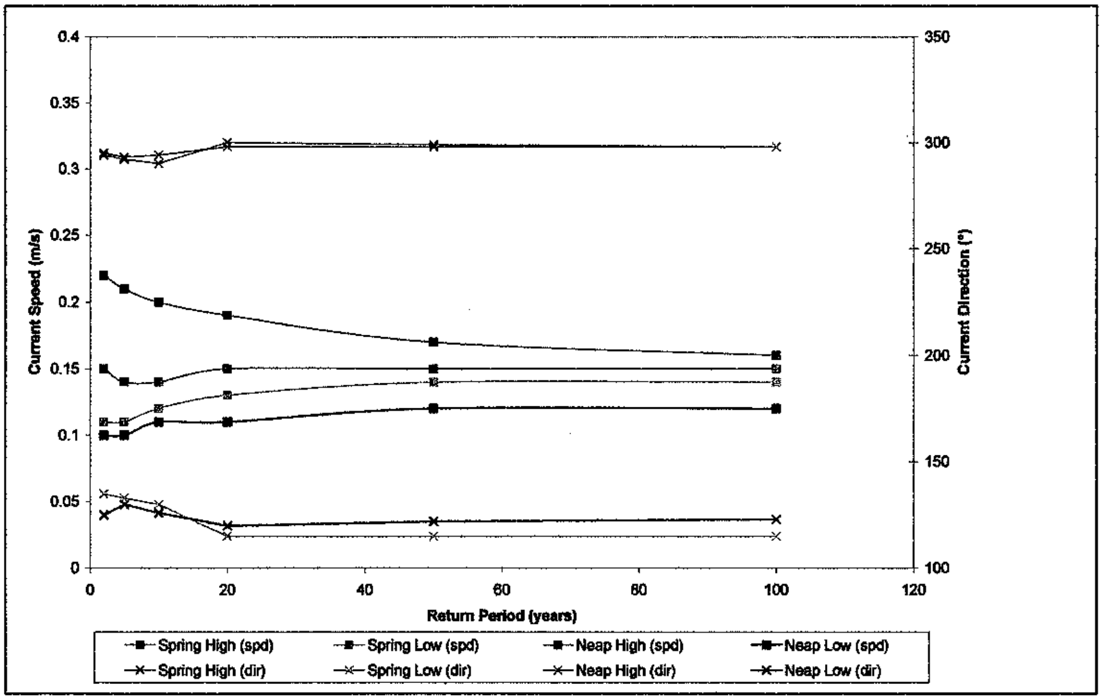


Figure 6.16: Current speeds and directions against various return periods at station 1

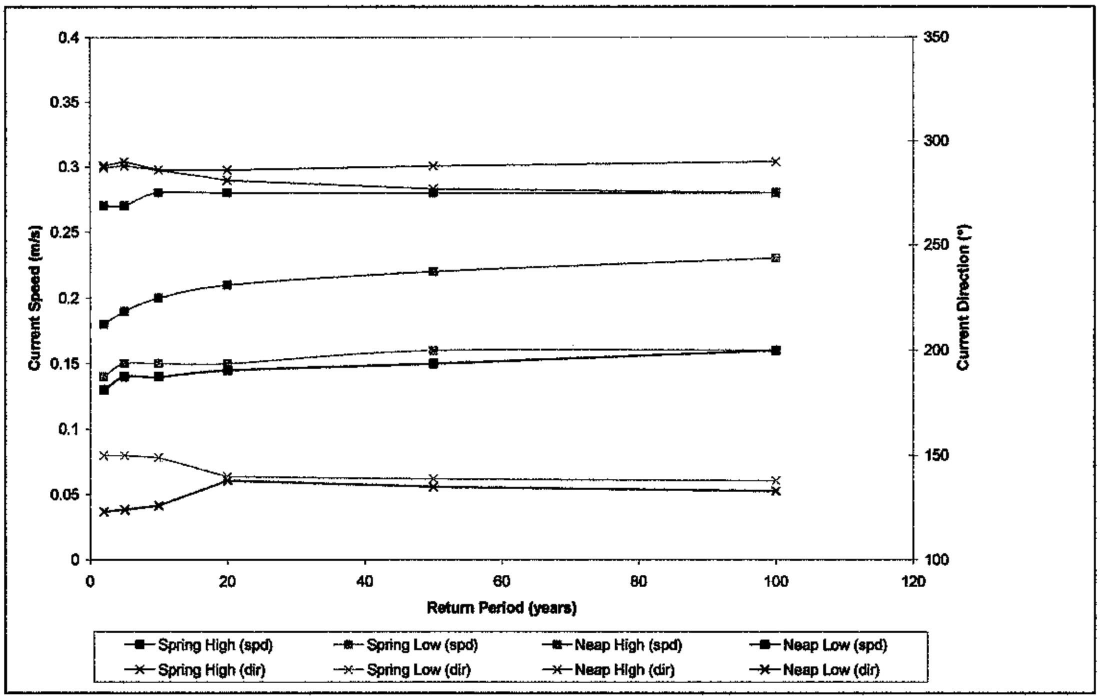


Figure 6.17: Current speeds and directions against various return periods at station 2

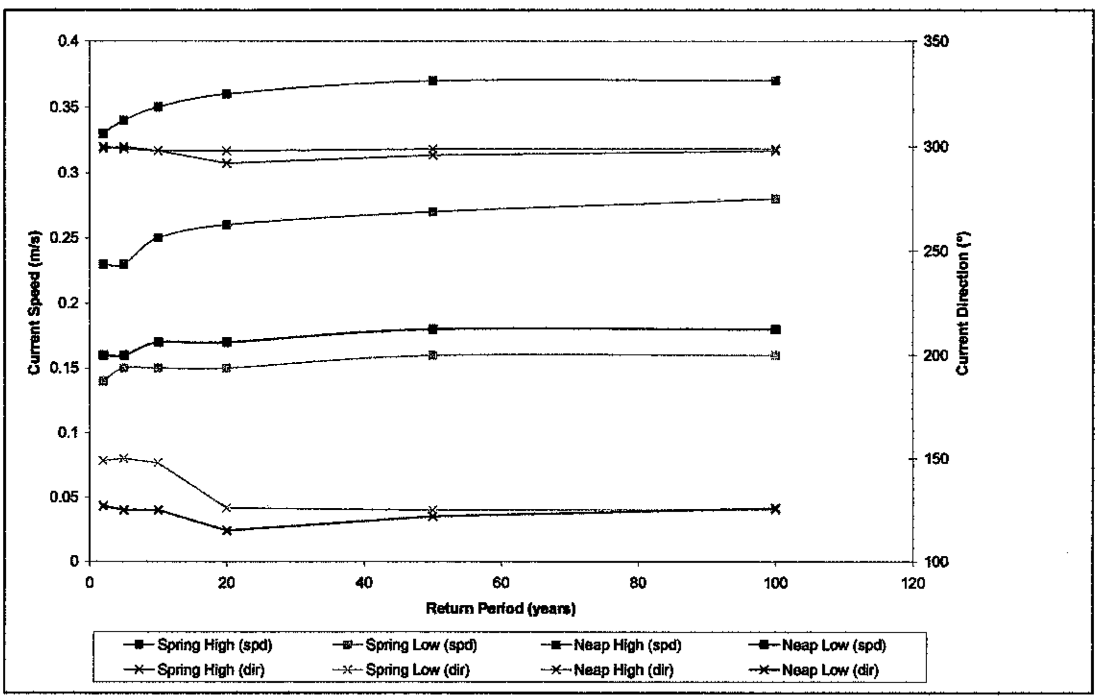


Figure 6.18: Current speeds and directions against various return periods at station 3

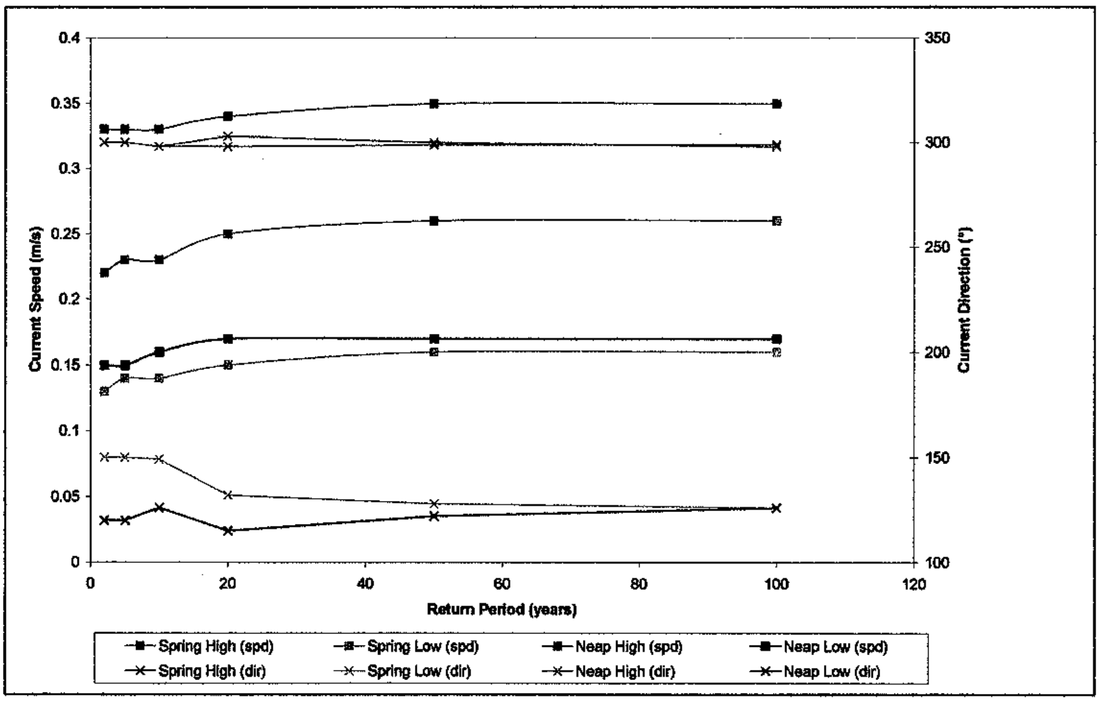


Figure 6.19: Current speeds and directions against various return periods at station 4

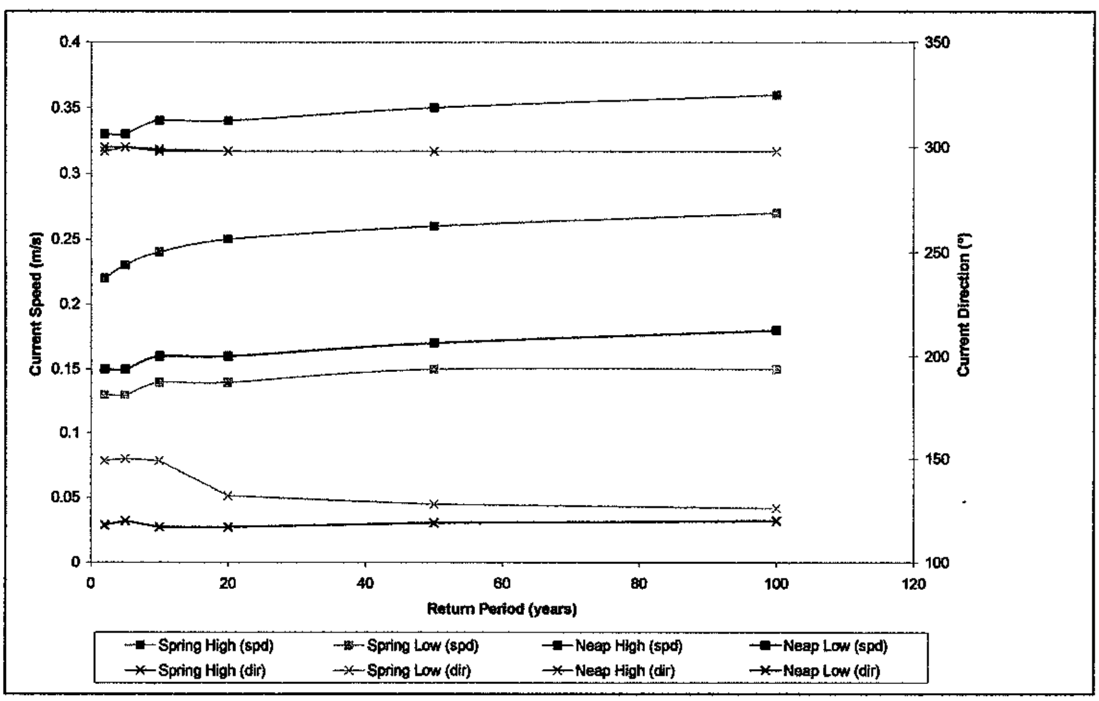


Figure 6.20: Current speeds and directions against various return periods at station 5

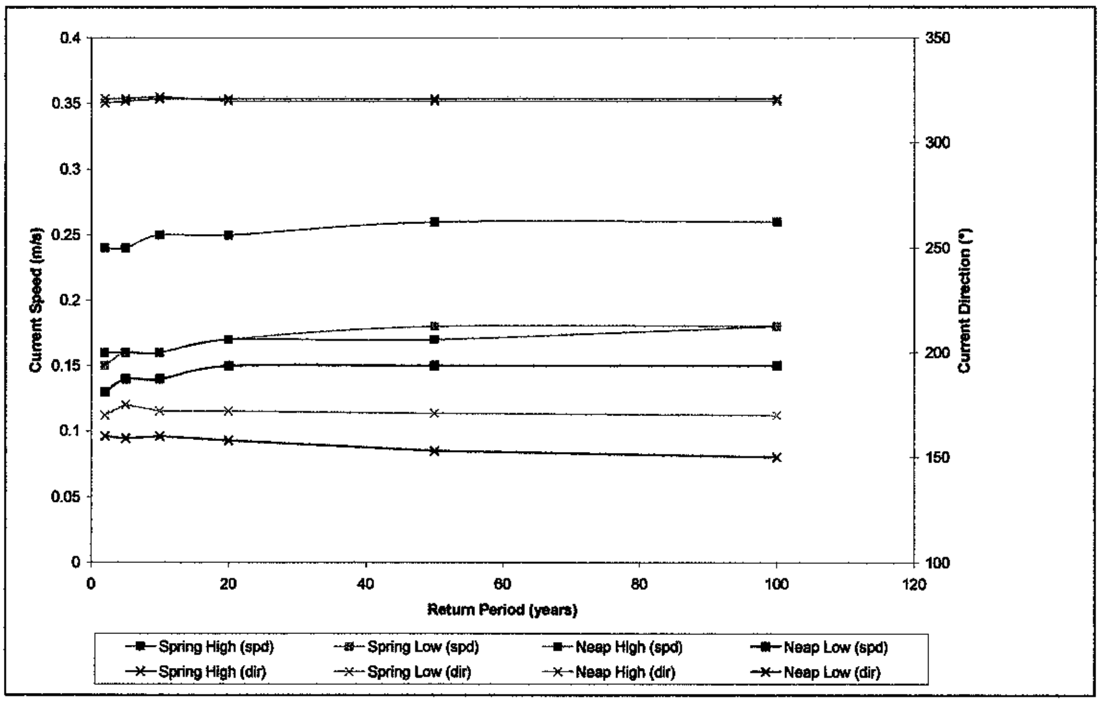


Figure 6.21: Current speeds and directions against various return periods at station 6

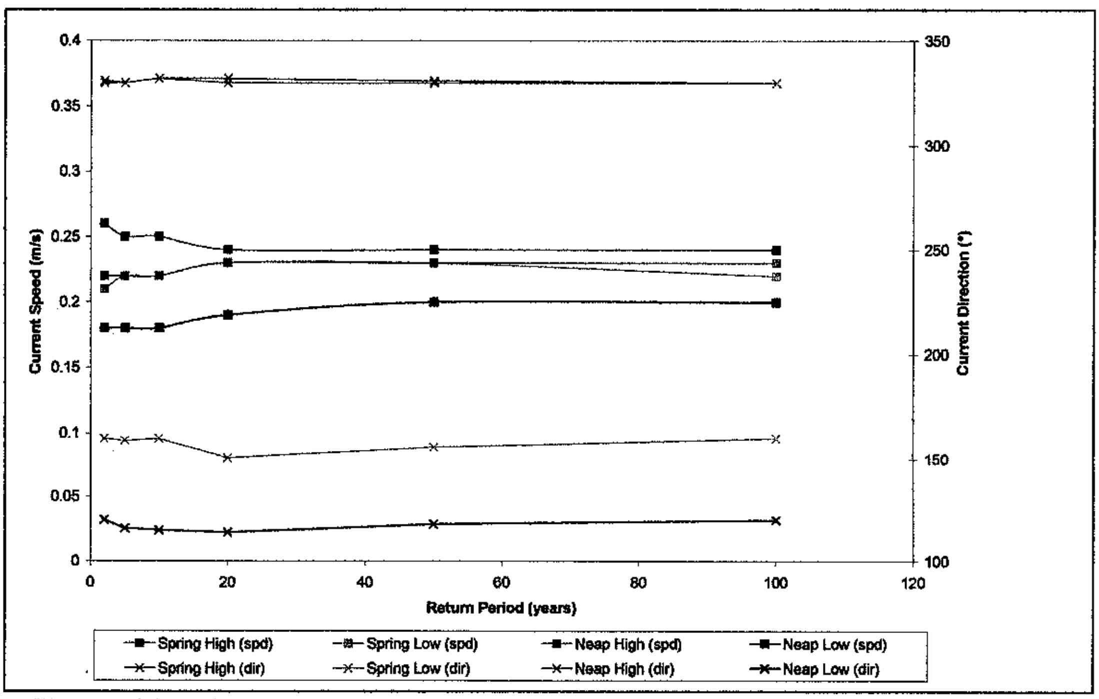


Figure 6.22: Current speeds and directions against various return periods at station 7

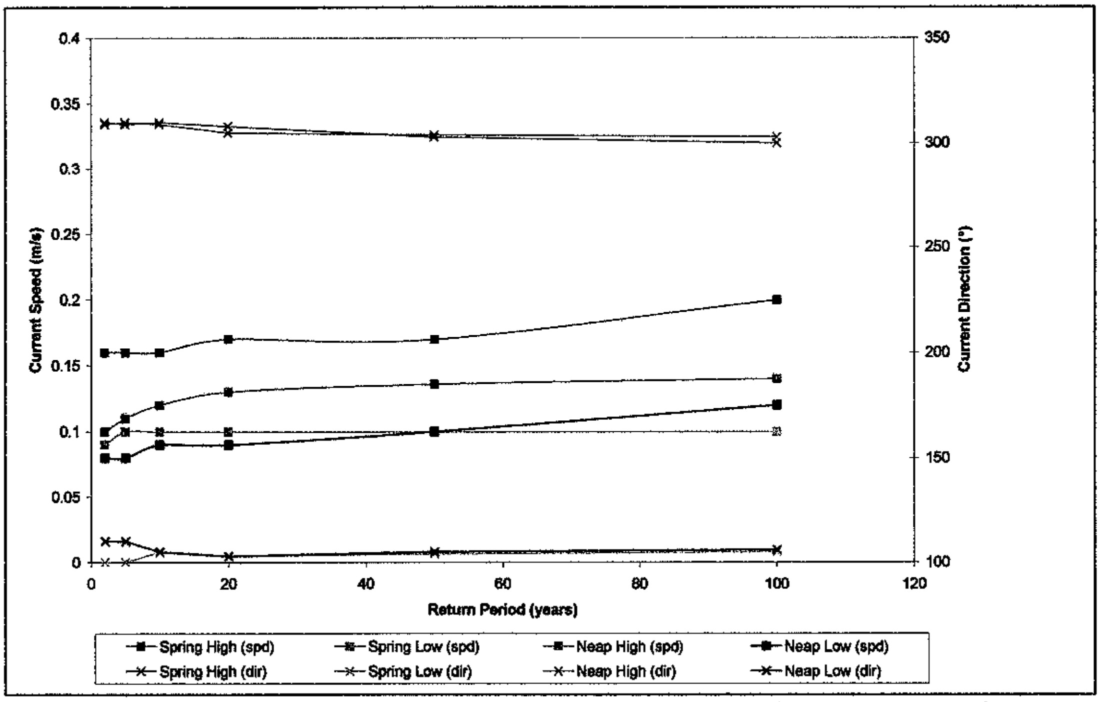


Figure 6.23: Current speeds and directions against various return periods at station 8

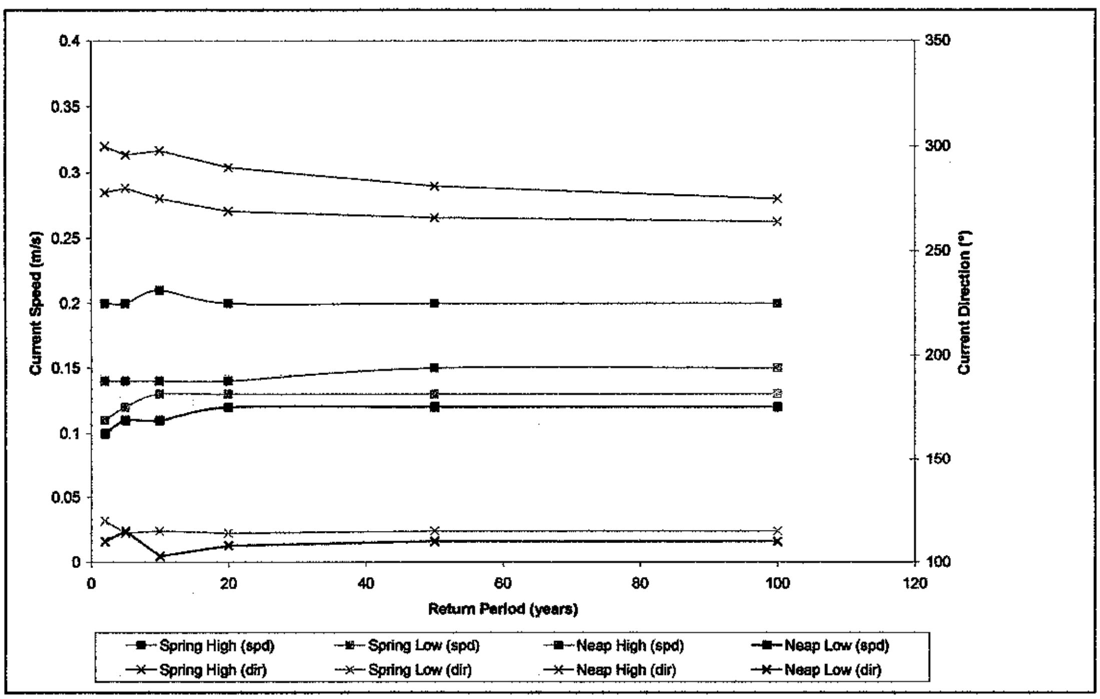


Figure 6.24: Current speeds and directions against various return periods at station 9

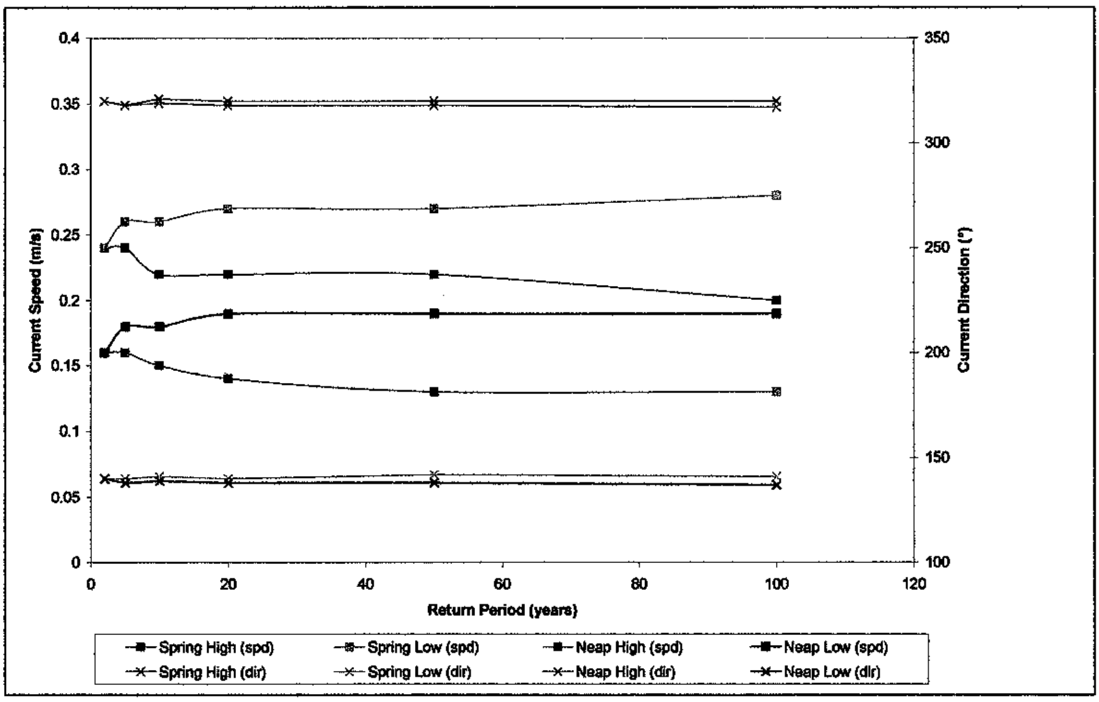


Figure 6.25: Current speeds and directions against various return periods at station 10

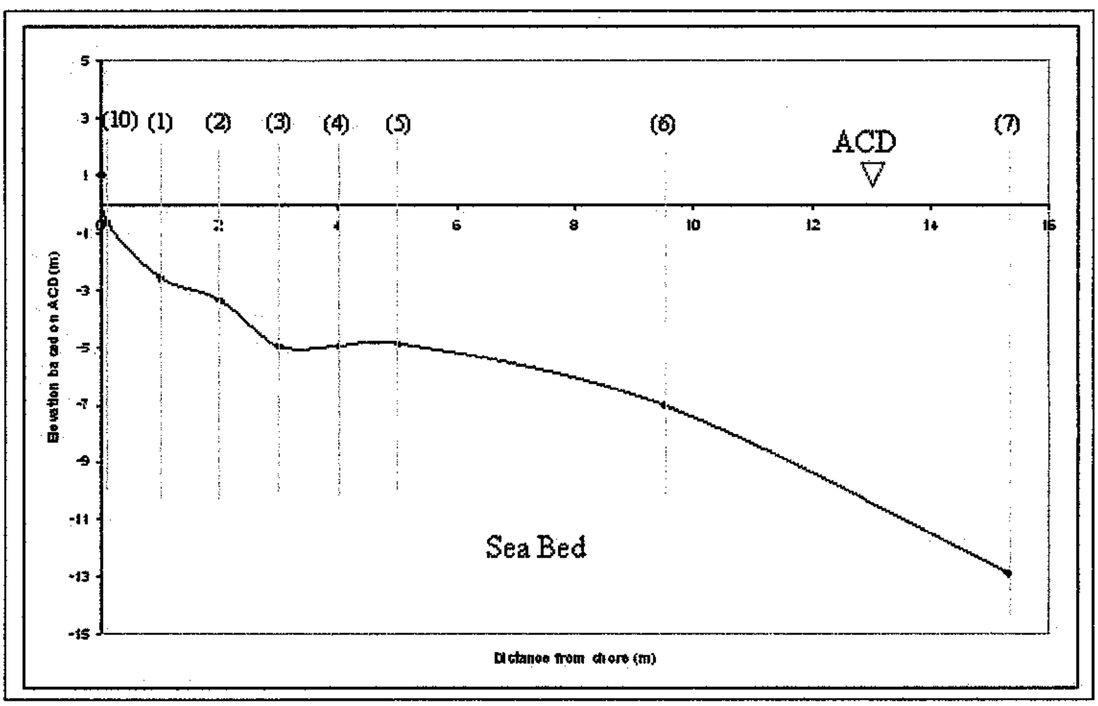


Figure 6.26: Cross section of sea bed (Station 10 to Station 7)

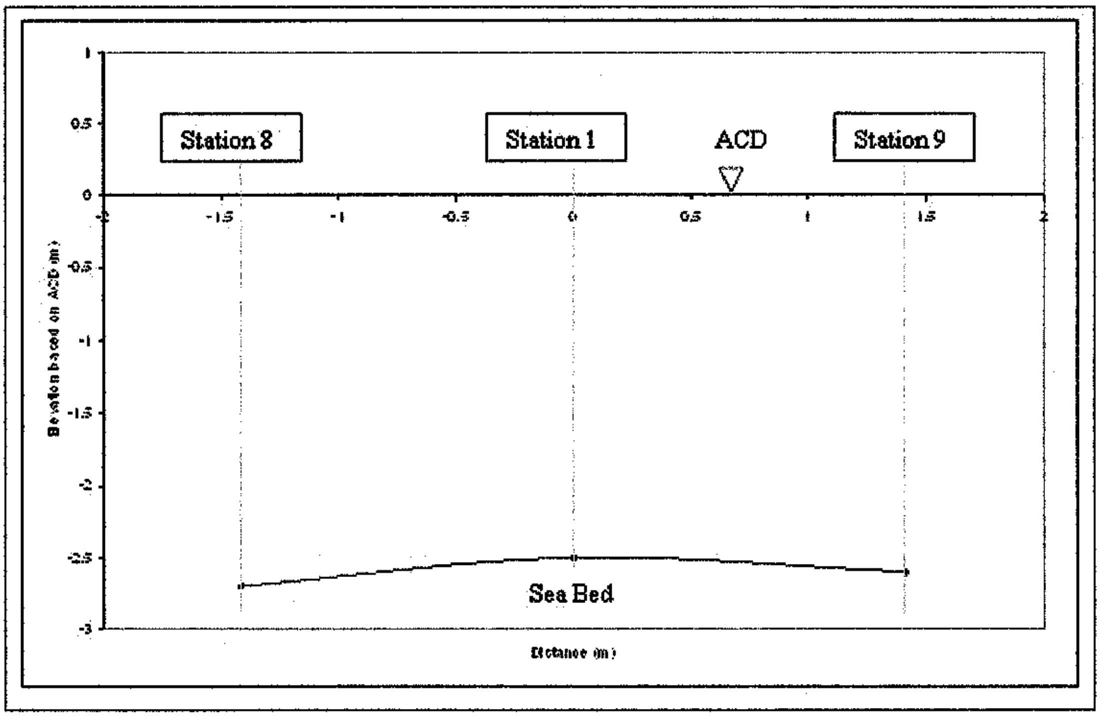


Figure 6.27: Cross section of bathymetry (Station 8, 1 and 9)

As shown from **Figure 6.16** to **Figure 6.25**, the current speeds are increasing from station 7 to station 3 and decreasing from station 3 to station 1 as the currents flow towards the shore. These phenomena can be explained by using **Figure 6.26**. At station 6 and station 7, both the stations are located in the water depth, measured 7 meter and 12.9 meter below ACD respectively. Thus, the current speeds are low during the spring high tide at 50 years, which are 0.26 m/s recorded at station 6 and 0.24 m/s at station 7. The current flows are not affected by the high water depth, enabling the current to flow with minimal energy in the region.

At station 5 onwards towards the shore, the currents enter a region with less deep water depth. At station 3, station 4 and station 5, these three stations have almost the same water depth, measured 4.9 meter, 4.9 meter and 4.8 meter below ACD respectively. Hence, the current speeds are higher during the spring high tide at 50 years, which are 0.37 m/s recorded at station 3, 0.35 m/s at station 4 and 0.35 m/s at station 5. The limitation of the water depth will affect the speed of the current flow. Hence, this will increase the speed of the current.

At station 1 and station 2, both the stations are located on the upslope of the beach with water depth of 2.5 meter and 3.3 meter below ACD respectively. But, results show that the current speeds during the spring high tide at 50 years are reduced to 0.17 m/s and 0.28 m/s respectively. This is because the currents are entering shallower water region and wave refraction occurs in this area. Therefore, some of the energy is dissipated in order to change the current direction in aligning to the bottom contour. At station 10, the incoming current speed is lower than the outgoing current speeds, which are 0.22 m/s and 0.27 m/s respectively at 50 years during spring high tide.

Overall, the dominant incoming direction of current flow is 300° with mean deviation of 15° during flood tide and during ebb tide, the direction of current flow is 125° with mean deviation of 15°.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 Recommendations

Improvements can be done to this project in order to produce a more reliable and accurate results from the modeling of the study area. These improvements are:

- Attend or request for MIKE 21 training, which is held by the DHI Water and Environment (M) Sdn Bhd. This is to improve the student for better understanding of the numerical modeling and also to gain some experience from the DHI engineers in simulating a model.
- Do some modeling exercises by following the examples that are given by the manuals. With these exercises, the students will greatly benefits and gain better understanding in the modeling.
- Regular contacts with the DHI engineers when the students are having difficulties with the MIKE 21 models. DHI engineers are willingly to help UTP students.
- It is best to have measured data for every types of model. This is because measured data can be used for calibration in order to compare the simulated resulted. Hence, it will significantly improve the accuracy of the results.

7.2 Conclusions

Firstly, Tanjung Kepah coast is identified as the study area for this project which was proposed by the officer from Department of Irrigation and Drainage, Malaysia (DID) Manjung District. Information on the study area gathered through the site investigation was background of the study area, problems faced at the study area, soil erosion, local activities and urban development, protective coastal structure and bed sampling. Besides this information, data on the environmental forces are obtained from the local authorities. These environmental forces are wind, wave, tidal elevation, current and topographic of the sea bottom.

The raw data collected from site investigation and local authorities are studied and interpreted through proper analysis methods. Analysis methods are done on the tidal fluctuations, current analysis, wind climate, and wave climate. Tidal fluctuations analysis was done to predict the tides fluctuation on March and April. Current analysis was done to study the current flow patterns during the ebb tide and flood tide. Wind climate analysis was done to interpret the dominant wind force in terms of direction and mean speed. Wave analysis was done to study and interpret the significant wave heights and wave periods and to find the extreme wave heights and wave periods with various return periods.

The coastal hydrodynamics of Tanjung Kepah is simulated by using MIKE 21 NSW and MIKE 21 HD. MIKE 21 NSW will simulate the significant wave heights and mean wave periods for various return periods. MIKE 21 HD will incorporate wave radiation stress simulated by MIKE 21 NSW to generate wind-wave induced currents and water depths. With these simulated results from both MIKE 21 NSW and MIKE 21 HD, the impacts of wave distribution and current flow patterns in Tanjung Kepah can be analyzed. Finally, this report can be used by the local authority officers as a reference in order to further study the existing coastal hydrodynamic of Tanjung Kepah. Besides, they can decide the preliminary preventive measures to be taken to protect the coast of Tanjung Kepah. Lastly, all the objectives of this project are achieved successfully.

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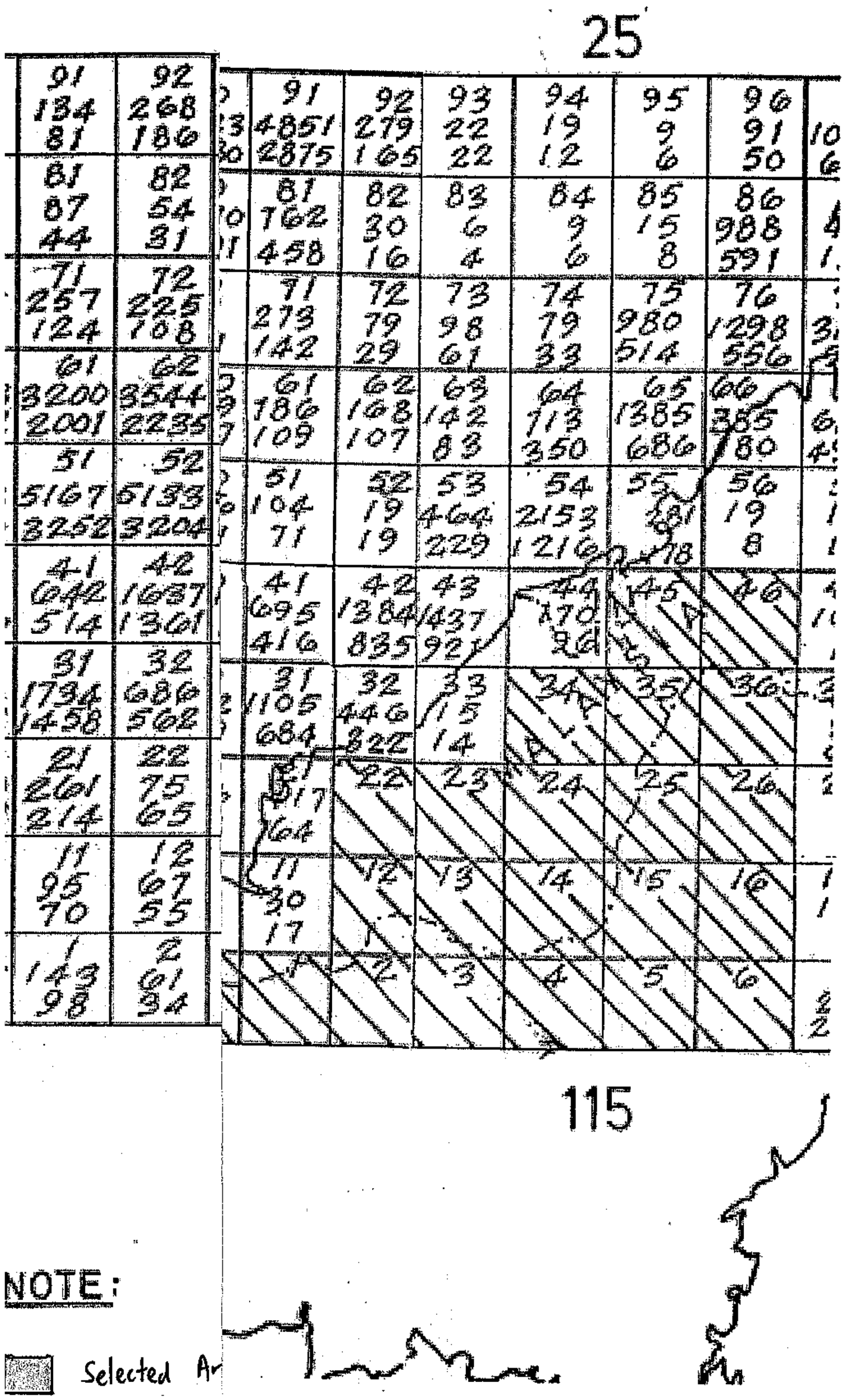
APPENDICES



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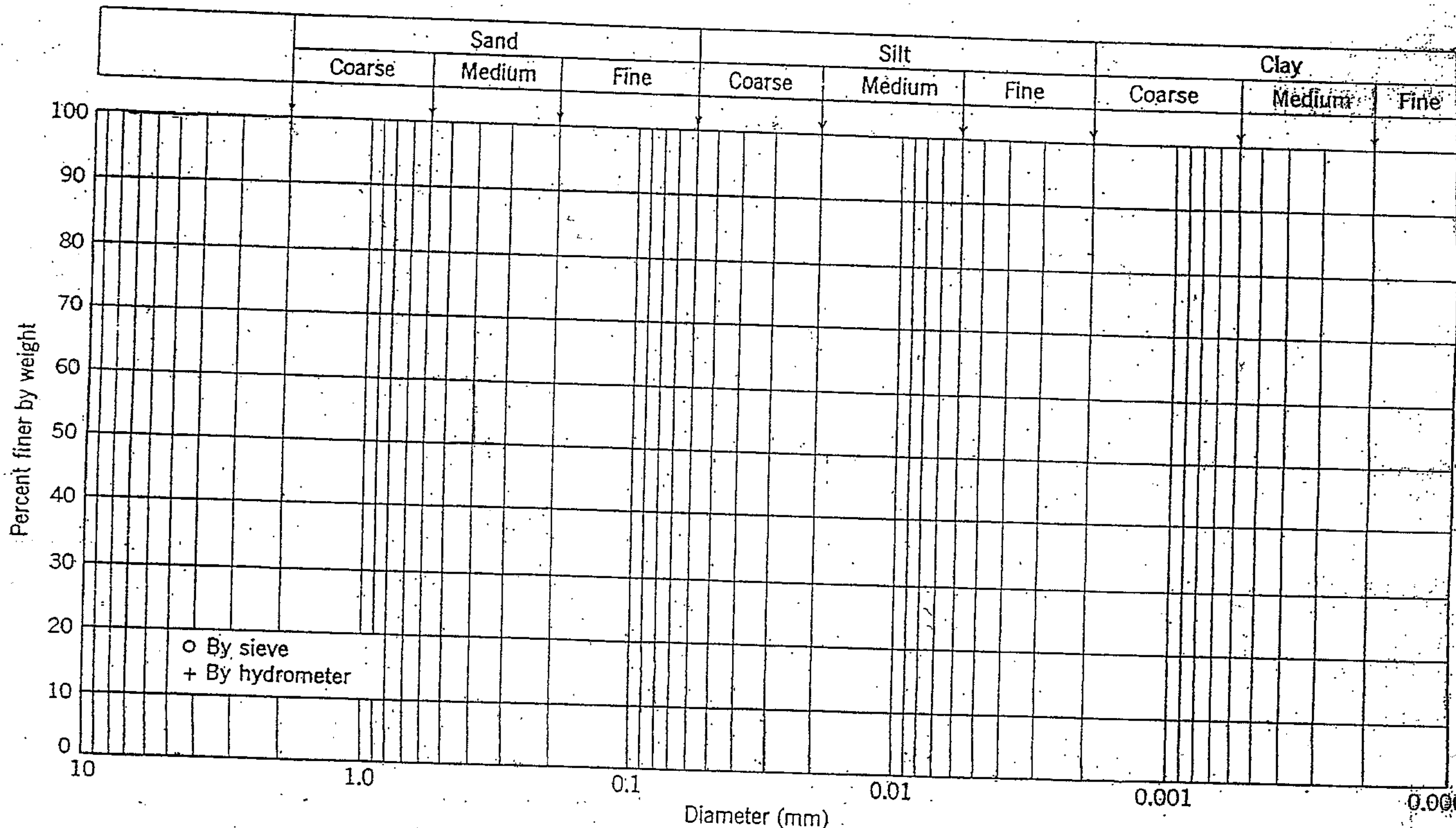


Particle size distribution curve.

ARAS PASANG SURUT PELABUHAN PIAWAI
TIDAL LEVELS AT STANDARD PORT

labuhan Piawai *andard Port*	Air Surut Falak Terendah *Lowest Astronomical Tide*	Air Surut Perbani Min *Mean Low Water Spring*	Air Surut Anak Min *Mean Low Water Neap*	Aras Laut Min *Mean Sea Level*	Air Pasang Anak Min *Mean High Water Neap*	Air Pasang Perbani Min *Mean High Water Spring*	Air Pasang Falak Tertinggi *Highest Astronomical Tide*	Pihak Berkuasa(a) *Authority for (a)*			Tahun Cerapan(b) *Years of Tidal Observations(b)*
								Cerapan *Observations*	Pemalar *Constants*	Ramalan *Predictions*	
	m.	m.	m.	m.	m.	m.	m.				
eluk Ewa	0.00	0.56	1.46	1.82	2.18	3.07	3.56	DNM	RMN	RMN	1991-04 (13)
uah	0.00	0.52	1.35	1.64	1.93	2.76	3.52	RMN	RMN	RMN	1997 (1 mth)
uala Perlis	0.00	0.63	1.53	1.87	2.21	3.11	3.80	DNM	RMN	RMN	1986 (1 mth)
edah Pier, Pulau Pinang	0.00	0.70	1.43	1.69	1.94	2.67	3.07	DNM	RMN	RMN	1992-03 (10)
ermaga Butterworth	0.00	0.72	1.44	1.68	1.91	2.63	3.03	RMN	RMN	RMN	1995-96 (1)
umut	0.00	0.77	1.47	1.87	2.26	2.97	3.47	DNM	RMN	RMN	1985-96 (11)
agan Datuk	0.00	0.44	1.20	1.67	2.14	2.90	3.40	RMN	RMN	RMN	1986 (1 mth)
elabuhan Klang	0.00	1.15	2.52	3.21	3.89	5.27	6.10	DMN	RMN	RMN	1985-96 (11)
ermatang Sedepa	0.00	0.85	2.08	2.71	3.34	4.57	5.31	ITS	ITS	RMN	1979 (1)
ort Dickson	0.00	0.31	1.14	1.55	1.96	2.79	3.50	ITS	ITS	RMN	1979 (1)
Tanjung Keling	0.00	0.57	1.17	1.48	1.79	2.39	3.10	DNM	RMN	RMN	1985-96 (11)
Kuala Batu Pahat	0.00	0.40	1.12	1.56	2.00	2.72	3.34	ITS	ITS	RMN	1979 (1)
Pulau Pisang	0.00	0.42	1.26	1.77	2.28	3.12	3.79	UTS	ITS	RMN	1979 (1)
Raffles Lighthouse	-0.10	0.51	1.20	1.67	2.40	2.89	3.50	ITS	ITS	PSA	1979 (1)
Tanjong Pagar	-0.30	-0.50	1.23	1.70	2.17	2.82	3.30	PSA	PSA	PSA	1984 (1)
Kukup	0.00	0.47	1.30	1.80	2.30	3.13	3.70	DNM	RMN	RMN	1986-98 (12)
Pel.Tanjung Pelepas	0.00	0.50	1.36	1.82	2.28	3.14	3.80	HA	HA	RMN	1999 (3 mths)
Johor Bahru	0.00	0.96	1.64	2.16	2.68	3.36	3.90	DNM	RMN	RMN	1984-98 (13)
Pasir Gudang	0.00	0.97	1.61	2.10	2.59	3.23	4.00	RMN	RMN	RMN	1989 (1)
Sembawang Shipyard	-0.30	0.76	1.36	1.88	2.40	3.07	3.90	PSA	PSA	PSA	1977-78 (1)
Sungai Belungkor	0.00	0.78	1.42	1.87	2.31	2.96	3.70	HA	FU	RMN	1986 (1 mth)

elabuhan Piawai *Standard Port*	Air Surut Falak Terendah *Lowest Astronomical Tide*	Air Surut Rendah Min *Mean Lower Low Water*	Air Surut Tinggi Min *Mean Higher Low Water*	Aras Laut Min *Mean Sea Level*	Air Pasang Rendah Min *Mean Lower High Water*	Air Pasang Tinggi Min *Mean Higher High Water*	Air Pasang Falak Tertinggi *Highest Astronomical Tide*	Pihak Berkuasa(a) *Authority for (a)*			Tahun Cerapan(b) *Years of Tidal Observations (b)*
								Cerapan *Observations*	Pemalar *Constants*	Ramalan *Predictions*	
	m.	m.	m.	m.	m.	m.	m.				
Pulau Batu Puteh (Horsburgh Lighthouse)	0.00	0.61	1.70	1.72	1.74	2.83	3.01	ITS	ITS	RMN	1979 (1)
Tanjung Sedili	0.00	0.48	1.61	1.70	1.79	2.91	3.13	DNM	RMN	RMN	1992-98 (5)
Mersing	0.00	0.42	1.66	1.79	1.92	3.16	3.56	RMN	RMN	RMN	1996 (1 mth)
Teluk Tekek	0.00	0.53	1.70	1.92	2.14	3.31	3.70	DNM	RMN	RMN	1986-96 (10)
Tanjung Gelang	0.00	0.53	1.56	1.94	2.31	3.35	3.83	DNM	RMN	RMN	1984-96 (12)
Tanjung Berhala	0.00	0.54	1.44	1.86	2.29	3.19	3.73	HA	FU	RMN	1985 (4 mths)
Kertih (Jeti Petronas)	0.00	0.46	1.21	1.69	2.16	2.91	3.70	RMN	RMN	RMN	1995 (1)
Chendering	0.00	0.64	1.23	1.73	2.23	2.82	3.06	DNM	RMN	RMN	1985-96 (11)
Kuala Terengganu	0.00	0.43	0.97	1.45	1.93	2.47	3.02	RMN	RMN	RMN	1988 (1)
Geting	0.00	0.22	0.53	0.75	0.96	1.27	1.77	DNM	RMN	RMN	1987-98 (11)

The above levels are referred to CHART DATUM, which is the same as the zero of the tidal predictions in all cases.

(a) Abbreviations.

DNM	Directorate of National Mapping, Malaysia.
FU	Institute for Atmospheric and Marine Sciences, Flinders University of South Australia.
HA	Local Harbour Authority.
ITS	International Tidal Survey.
PSA	Hydrographic Department, Port of Singapore Authority.
RMN	Hydrographic Department, Royal Malaysian Navy.

(b) The years between which the observations were obtained are given, the number of complete years observations in brackets.

All predictions are calculated by the harmonic method.

Tidal Levels

MARCH

Day	Time	Height (m)	Day	Time	Height (m)	Day	Time	Height (m)
1	5:04	3.0	13	3:43	2.5	25	0:08	2.1
W	11:29	0.0	M	10:01	0.6	Sa	7:02	1.1
	18:00	3.1		16:23	2.7		13:46	2.3
	23:58	0.6		22:25	0.9		19:52	1.3
2	5:44	2.9	14	4:09	2.6	26	1:35	2.3
Th	12:05	0.0	T	10:28	0.5	Su	8:11	0.8
	13:05	3.2		16:51	2.8		14:46	2.6
3	0:37	0.6		22:52	0.9		20:50	1.1
F	6:23	2.8	15	4:36	2.7	27	2:32	2.5
	12:38	0.2	W	10:53	0.4	M	9:00	0.5
	19:03	3.1	○	17:15	2.8		15:33	2.9
4	1:13	0.6		23:17	0.8		21:37	0.9
Sa	7:01	2.6	16	5:02	2.7	28	3:20	2.7
	13:09	0.5	Th	11:17	0.4	T	9:43	0.3
	19:31	2.9		17:38	2.9		16:14	3.1
5	1:49	0.7		23:43	0.7		22:19	0.7
Su	7:38	2.4	17	5:30	2.7	29	4:05	2.9
	13:40	0.8	F	11:41	0.5	W	10:23	0.2
	19:57	2.7		18:01	2.9	●	16:52	3.2
6	2:24	0.9	18	0:10	0.7		22:58	0.7
M	8:18	2.1	Sa	5:58	2.6	30	4:48	2.9
	14:12	1.1		12:06	0.6	Th	11:00	0.2
	20:24	2.4		18:23	2.9		17:25	3.3
7	3:04	1.1	19	0:38	0.7		23:36	0.5
T	9:09	1.9	Su	6:26	2.5	31	5:29	2.9
	14:53	1.4		12:31	0.7	F	11:36	0.3
	21:02	2.1		18:44	2.8		17:55	3.2
8	4:03	1.2	20	1:05	0.7			
W	11:13	1.8	M	6:55	2.4			
	16:40	1.6		12:59	0.8			
	22:48	1.9		19:08	2.7			
9	6:48	1.3	21	1:34	0.8			
Th	14:02	2.0	T	7:28	2.3			
	20:08	1.5		13:31	1.0			
10	1:43	1.9		19:38	2.5			
F	8:13	1.2	22	2:09	1.0			
	14:50	2.2	W	8:11	2.2			
	20:56	1.3		14:15	1.2			
11	2:39	2.1		20:21	2.3			
Sa	8:57	1.0	23	3:03	1.2			
	15:24	2.4	Th	9:23	2.0			
	21:29	1.1		15:30	1.5			
12	3:14	2.3		21:37	2.1			
Su	9:32	0.8	24	4:44	1.3			
	15:55	2.5	F	12:03	2.0			
	21:58	1.0		18:05	1.5			

Tidal Levels

APRIL

Day	Time	Height (m)	Day	Time	Height (m)	Day	Time	Height (m)
1	0:11	0.5	13	4:11	2.6	25	2:05	2.5
Sa	6:08	2.7	Th	10:15	0.7	T	8:21	0.7
	12:09	0.5	○	16:35	3.0		14:55	3.1
	18:28	3.1		22:50	0.7		21:14	0.9
2	0:46	0.5	14	4:42	2.7	26	2:57	2.7
Su	6:46	2.6	F	10:43	0.7	W	9:07	0.6
	12:42	0.8		17:00	3.0		16:36	3.2
	18:50	2.9		23:18	0.7		21:56	0.7
3	1:18	0.6	15	5:13	2.7	27	3:46	2.8
M	7:23	2.4	Sa	11:11	0.7	Th	9:50	0.6
	13:14	1.1		17:24	3.0		16:13	3.3
	19:15	2.6		23:45	0.6		22:36	0.6
4	1:50	0.8	16	5:43	2.6	28	4:32	2.8
T	8:01	2.2	Su	11:40	0.8	F	10:31	0.6
	13:49	1.3		17:50	3.0	●	16:47	3.2
	19:42	2.4	17	0:14	0.6		23:13	0.6
5	2:23	1.1	M	6:14	2.6	29	5:15	2.8
W	8:51	2.1		12:10	0.9	Sa	11:09	0.8
	14:36	1.6		18:16	2.9		17:19	3.2
	20:18	2.1	18	0:43	0.7		23:48	0.6
6	3:13	1.3	T	6:47	2.5	30	5:55	2.7
Th	10:36	2.0		12:43	1.1	Su	11:46	0.9
	16:48	1.7		18:45	2.7		17:49	3.0
	21:56	1.9	19	1:17	0.8			
7	5:27	1.4	W	7:25	2.4			
F	13:12	2.1		13:23	1.2			
	19:43	1.6		19:22	2.6			
8	1:12	1.9	20	1:58	1.0			
Sa	7:24	1.3	Th	8:19	2.3			
	14:06	2.3		14:19	1.4			
	20:28	1.4		20:11	2.4			
9	2:08	2.1	21	2:58	1.2			
Su	8:13	1.2	F	6:50	2.2			
	14:42	2.5		15:48	1.6			
	21:00	1.2		21:33	2.2			
10	2:42	2.3	22	4:34	1.2			
M	8:49	1.0	Sa	11:53	2.3			
	15:13	2.7		18:03	1.6			
	21:29	1.1		23:38	2.2			
11	3:12	2.4	23	6:18	1.1			
T	9:19	0.8	Su	13:13	2.6			
	15:42	2.8		19:30	1.4			
	21:56	1.0	24	1:04	2.3			
12	3:42	2.6	M	7:27	0.9			
W	9:48	0.7		14:09	2.9			
	16:09	2.9		20:28	1.2			
	22:23	0.8						

LUMUT, PERAK DARUL RIDZUAN

Lat 04 14 N Long 100 37 E

TIME ZONE -0800 TIMES AND HEIGHTS OF HIGH AND LOW WATERS 2006

JANUARY

Day	Time	m	Day	Time	m
1 Su	0441	3.0	16 M	0508	2.7
	1123	0.3		1146	0.4
	1750	2.7		1811	2.6
	2335	1.0		2355	1.1
2 M	0523	3.0	17 T	0536	2.7
	1205	0.2		1214	0.5
	1838	2.8		1840	2.6
3 T	0022	1.0	18 W	0024	1.1
	0604	2.9		0604	2.7
	1246	0.3		1239	0.5
	1923	2.8		1908	2.6
4 W	0109	1.1	19 Th	0056	1.1
	0645	2.8		0633	2.6
	1326	0.3		1306	0.6
	2008	2.8		1936	2.6
5 Th	0159	1.2	20 F	0132	1.2
	0730	2.5		0703	2.5
	1408	0.5		1332	0.7
	2053	2.8		2006	2.6
6 F	0253	1.3	21 Sa	0209	1.2
	0815	2.4		0737	2.3
	1449	0.7		1400	0.8
	2139	2.8		2037	2.6
7 Sa	0353	1.3	22 Su	0252	1.3
	0918	2.2		0815	2.1
	1536	1.0		1433	1.0
	2230	2.7		2113	2.5
8 Su	0506	1.3	23 M	0342	1.3
	1038	2.0		0907	2.0
	1634	1.2		1518	1.1
	2330	2.6		2203	2.4
9 M	0636	1.2	24 T	0454	1.3
	1224	1.9		1031	1.9
	1753	1.4		1628	1.3
				2324	2.3
10 T	0038	2.5	25 W	0638	1.2
	0744	1.0		1247	1.9
	1401	2.1		1824	1.4
	1928	1.4			
11 W	0144	2.5	26 Th	0103	2.3
	0840	0.9		0757	1.0
	1507	2.2		1412	2.1
	2046	1.3		1957	1.3
12 Th	0240	2.5	27 F	0210	2.4
	0926	0.7		0856	0.8
	1553	2.4		1513	2.3
	2139	1.2		2104	1.1
13 F	0326	2.6	28 Sa	0304	2.6
	1007	0.6		0945	0.5
	1634	2.5		1608	2.5
	2221	1.2		2157	1.0
14 Sa	0406	2.6	29 Su	0351	2.8
	1043	0.5		1031	0.3
	1709	2.5		1658	2.7
	2255	1.1		2246	0.9
15 Su	0438	2.7	30 M	0435	2.9
	1116	0.5		1112	0.1
	1741	2.5		1744	2.8
	2326	1.1		2331	0.8
			31 T	0517	3.0
				1153	0.0
				1826	3.0

FEBRUARY

Day	Time	m	Day	Time	m
1 W	0015	0.8	16 Th	0007	0.9
	0557	2.9		0547	2.7
	1230	0.0		1212	0.4
	1905	3.0		1837	2.8
2 Th	0057	0.8	17 F	0035	0.9
	0638	2.8		0615	2.6
	1306	0.1		1236	0.4
	1940	3.0		1900	2.8
3 F	0139	0.9	18 Sa	0104	0.9
	0717	2.6		0643	2.5
	1339	0.4		1300	0.6
	2013	2.9		1923	2.7
4 Sa	0222	0.9	19 Su	0135	0.9
	0758	2.4		0712	2.3
	1413	0.7		1325	0.7
	2047	2.7		1947	2.6
5 Su	0307	1.0	20 M	0207	1.0
	0843	2.1		0745	2.2
	1449	1.0		1354	0.9
	2123	2.5		2015	2.5
6 M	0401	1.1	21 T	0245	1.1
	0946	1.9		0827	2.0
	1535	1.3		1435	1.1
	2213	2.3		2055	2.3
7 T	0523	1.2	22 W	0338	1.2
	1151	1.8		0934	1.9
	1707	1.5		1540	1.3
	2349	2.1		2207	2.1
8 W	0719	1.2	23 Th	0523	1.3
	1409	1.9		1210	1.9
	1949	1.5		1759	1.4
9 Th	0137	2.1	24 F	0033	2.1
	0831	1.0		0733	1.1
	1508	2.1		1401	2.1
	2100	1.3		1955	1.3
10 F	0244	[illegible]	25 Sa	0156	2.3
	0918	0.8		0839	0.8
	1547	2.3		1506	2.4
	2142	1.2		2101	1.1
11 Sa	0327	2.4	26 Su	0252	2.5
	0956	0.7		0929	0.5
	1622	2.4		1557	2.6
	2216	1.0		2152	0.9
12 Su	0401	2.5	27 M	0339	2.8
	1029	0.5		1012	0.2
	1653	2.8		1642	2.9
	2246	1.0		2237	0.8
13 M	0429	2.6	28 T	0423	2.9
	1058	0.4		1052	0.0
	1723	2.6		1723	3.0
	2313	1.0		2319	0.7
14 T	0455	2.7			
	1124	0.3			
	1749	2.7			
	2339	0.9			
15 W	0521	2.7			
	1149	0.3			
	1813	2.7			

MARCH

Day	Time	m	Day	Time	m
1 W	0504	3.0	16 Th	0502	2.7
	1129	0.0		1117	0.4
	1800	3.1		1738	2.9
	2358	0.6		2343	0.7
2 Th	0544	2.9	17 F	0530	2.7
	1205	0.0		1141	0.5
	1834	3.2		1801	2.9
3 F	0037	0.6	18 Sa	0010	0.7
	0623	2.8		0558	2.6
	1238	0.2		1206	0.6
	1903	3.1		1823	2.9
4 Sa	0113	0.6	19 Su	0038	0.7
	0701	2.6		0626	2.5
	1309	0.5		1231	0.7
	1931	2.9		1844	2.8
5 Su	0149	0.7	20 M	0105	0.7
	0738	2.4		0655	2.4
	1340	0.8		1259	0.8
	1957	2.7		1908	2.7
6 M	0224	0.9	21 T	0134	0.8
	0818	2.1		0728	2.3
	1412	1.1		1331	1.0
	2024	2.4		1938	2.5
7 T	0304	1.1	22 W	0209	1.0
	0909	1.9		0811	2.2
	1453	1.4		1415	1.2
	2102	2.1		2021	2.3
8 W	0403	1.2	23 Th	0303	1.2
	1113	1.8		0923	2.0
	1640	1.6		1530	1.5
	2248	1.9		2137	2.1
9 Th	0648	1.3	24 F	0444	1.3
	1402	2.0		1203	2.0
	2008	1.5		1805	1.5
10 F	0143	1.9	25 Sa	0008	2.1
	0813	1.2		0702	1.1
	1450	2.2		1346	2.3
	2056	1.3		1952	1.3
11 Sa	0239	2.1	26 Su	0135	2.3
	0857	1.0		0811	0.9
	1524	2.4		1446	2.6
	2129	1.1		2050	1.1
12 Su	0314	2.3	27 M	0232	2.5
	0932	0.8		0900	0.5
	1555	2.5		1533	2.9
	2158	1.0		2137	0.9
13 M	0343	2.5	28 T	0320	2.7
	1001	0.6		0943	0.3
	1623	2.7		1614	3.1
	2225	0.9		2219	0.7
14 T	0409	2.6	29 W	0405	2.9
	1028	0.5		1023	0.2
	1651	2.8		1652	3.2
	2252	0.9		2258	0.6
15 W	0436	2.7	30 Th	0448	2.9
	1053	0.4		1100	0.2
	1715	2.8		1725	3.3
	2317	0.8		2336	0.5
			31 F	0529	2.9
				1136	0.3
				1755	3.2

APRIL

Day	Time	m	Day	Time	m
1 Sa	0011	0.5	16 Su	0543	2.6
	0608	2.7		1140	0.8
	1209	0.5		1750	3.0
	1823	3.1			
2 Su	0046	0.5	17 M	0014	0.6
	0646	2.6		0614	2.6
	1242	0.8		1210	0.9
	1850	2.9		1816	2.9
3 M	0118	0.6	18 T	0043	0.7
	0723	2.4		0647	2.5
	1314	1.1		1243	1.1
	1915	2.6		1845	2.7
4 T	0150	0.8	19 W	0117	0.8
	0801	2.2		0725	2.4
	1349	1.3		1323	1.2
	1942	2.4		1922	2.6
5 W	0223	1.1	20 Th	0156	1.0
	0851	2.1		0819	2.3
	1436	1.6		1419	1.4
	2018	2.1		2011	2.4
6 Th	0313	1.3	21 F	0258	1.2
	1036	2.0		[illegible]	2.2
	1648	1.7		1548	1.6
	2156	1.9		2133	2.2
7 F	0527	1.4	22 Sa	0434	1.2
	1312	2.1		1153	2.3
	1943	1.6		1803	1.6
				2338	2.2
8 Sa	[illegible]	1.9	23 Su	0618	1.1
	0724	1.3		1313	2.6
	1406	2.3		1930	1.4
	2028	1.4			
9 Su	0208	2.1	24 M	0104	2.3
	0813	1.2		0727	0.9
	1442	2.5		1409	[illegible]
	2100	1.2		2028	[illegible]
10 M	0242	2.3	25 T	0205	2.5
	0849	1.0		0821	[illegible]
	1513	2.7		1455	3.1
	2129	1.1		2114	0.9
11 T	0312	2.4	26 W	0257	2.7
	0919	0.8		0907	0.6
	1542	2.8		1536	3.2
	2156	1.0		2156	0.7
12 W	0342	2.6	27 Th	0346	2.8
	0948	0.7		0950	0.5
	1609	2.9		1613	3.3
	2223	0.8		[illegible]	0.5
13 Th	0411	2.6	28 F	0432	2.8
	1015	0.7		1031	0.6
	1635	3.0		1647	3.2
	2250	0.7		2312	0.5
14 F	0442	2.7	29 Sa	0515	2.8
	1043	0.7		1109	0.6
	1700	3.0		1719	3.2
	2318	0.7		2348	0.5
15 Sa	0513	2.7	30 Su	0555	2.7
	1111	0.7		1146	0.9
	1724	3.0		1749	3.0
	2345	0.6			

LUMUT, PERAK DARUL RIDZUAN

Lat 04 14 N Long 100 37 E

ME ZONE -0800 — TIMES AND HEIGHTS OF HIGH AND LOW WATERS — 2006

MAY

Day	Time	m	Day	Time	m
	0022	0.6	16	0609	2.6
	0634	2.6		1200	1.1
	1223	1.1	T	1759	2.9
	1819	2.8			
	0054	0.7	17	0035	0.7
	0711	2.5		0650	2.6
	1258	1.3	W	1241	1.3
	1848	2.6		1836	2.8
	0126	0.9	18	0115	0.8
	0751	2.4		0729	2.5
	1338	1.5	Th	1331	1.4
	1919	2.4		1919	2.7
	0202	1.1	19	0203	0.9
	0841	2.3		0842	2.5
	1430	1.7	F	1434	1.6
	2001	2.2		2012	2.5
	0249	1.3	20	0301	1.1
	0959	2.2		1002	2.5
	1608	1.8	Sa	1558	1.6
	2115	2.0		2126	2.4
	0406	1.4	21	0413	1.1
	1149	2.3		1122	2.7
	1827	1.7	Su	1737	1.6
	2331	2.0		2302	2.3
	0547	1.4	22	0530	1.1
	1256	2.5		1228	2.8
	1936	1.5	M	1856	1.4
	0105	2.1	23	0027	2.3
	0655	1.3		0638	1.1
	1341	2.6	T	1323	3.0
	2017	1.4		1957	1.2
	0154	2.2	24	0137	2.4
	0744	1.2		0737	1.0
	1419	2.8	W	1412	3.1
	2050	1.2		2048	1.0
	0234	2.4	25	0238	2.5
	0824	1.1		0832	1.0
	1452	2.9	Th	1456	3.1
	2121	1.0		2132	0.8
	0310	2.5	26	0332	2.6
	0902	1.0		0923	1.0
	1523	3.0	F	1537	3.1
	2151	0.9		2212	0.6
	0346	2.6	27	0421	2.7
	0938	1.0		1008	1.1
	1553	3.0	Sa	1614	3.1
	2222	0.8	●	2252	0.6
	0422	2.6	28	0506	2.7
	1013	1.0		1053	1.1
	1624	3.0	Su	1651	3.0
	2253	0.7		2328	0.6
	0457	2.7	29	0548	2.7
	1048	1.0		1133	1.2
	1654	3.0	M	1725	2.9
	2325	0.6			
	0533	2.7	30	0005	0.7
	1123	1.1		0626	2.6
	1726	3.0	T	1210	1.3
	2359	0.7		1758	2.8
			31	0039	0.8
				0704	2.5
			W	1249	1.4
				1831	2.7

JUNE

Day	Time	m	Day	Time	m
1	0113	0.9	16	0116	0.7
	0743	2.5		0753	2.7
Th	1328	1.5	F	1339	1.4
	1906	2.6		1917	2.8
2	0148	1.1	17	0200	0.8
	0826	2.5		0846	2.8
F	1416	1.6	Sa	1437	1.5
	1945	2.4		2008	2.6
3	0226	1.2	18	0249	0.9
	0918	2.5		0941	2.8
Sa	1518	1.7	Su	1543	1.5
	2037	2.2		2109	2.4
4	0313	1.3	19	0341	1.0
	1019	2.5		1039	2.8
Su	1640	1.7	M	1658	1.5
	2147	2.1		2225	2.3
5	0411	1.4	20	0442	1.1
	1124	2.6		1138	2.9
M	1807	1.6	T	1815	1.4
	2318	2.1		2352	2.2
6	0522	1.4	21	0551	1.2
	1223	2.5		1238	2.9
T	1911	1.5	W	1923	1.2
7	0016	2.1	22	0115	2.3
	0629	1.4		0700	1.3
W	1314	2.7	Th	1333	2.9
	1959	1.3		2022	1.0
8	0148	2.2	23	0226	2.4
	0727	1.3		0809	1.3
Th	1359	2.8	F	1424	2.9
	2039	1.1		2111	0.9
9	0237	2.4	24	0326	2.5
	0620	1.3		0911	1.3
F	1439	2.8	Sa	1513	2.9
	2117	1.0		2156	0.8
10	0321	2.5	25	0417	2.6
	0907	1.2		1003	1.3
Sa	1519	2.9	Su	1556	2.9
	2155	0.8		2238	0.7
11	0403	2.6	26	0502	2.6
	0951	1.2		1048	1.3
Su	1557	3.0	M	1637	2.9
○	2234	0.7	●	2317	0.7
12	0446	2.7	27	0542	2.6
	1033	1.2		1127	1.3
M	1635	3.0	T	1712	2.9
	2312	0.6		2353	0.7
13	0529	2.7	28	0619	2.6
	1116	1.2		1203	1.3
T	1713	3.0	W	1745	2.8
	2353	0.6			
14	0614	2.7	29	0026	0.7
	1200	1.2		0653	2.6
W	1752	3.0	Th	1237	1.4
				1816	2.8
15	0034	0.6	30	0056	0.6
	0702	2.7		0724	2.6
Th	1247	1.3	F	1312	1.4
	1833	2.9		1848	2.7

JULY

Day	Time	m	Day	Time	m
1	0125	0.9	16	0143	0.5
	0758	2.6		0823	3.0
Sa	1351	1.5	Su	1421	1.2
	1923	2.5		1955	2.7
2	0155	1.0	17	0223	0.7
	0834	2.7		0904	2.9
Su	1435	1.5	M	1513	1.3
	2001	2.4		2046	2.5
3	0228	1.1	18	0305	1.0
	0913	2.6		0949	2.8
M	1525	1.5	T	1612	1.3
	2048	2.2		2151	2.3
4	0308	1.2	19	0356	1.2
	0959	2.6		1042	2.7
T	1626	1.5	W	1725	1.3
	2150	2.1		2321	2.1
5	0358	1.4	20	0508	1.4
	1054	2.6		1151	2.6
W	1743	1.5	Th	1850	1.2
	2319	2.1			
6	0510	1.5	21	0107	2.2
	1202	2.5		0646	1.5
Th	1857	1.4	F	1307	2.5
				2004	1.1
7	0057	2.1	22	0231	2.3
	0637	1.5		0819	1.5
F	1310	2.6	Sa	1414	2.5
	1957	1.2		2101	1.0
8	0205	2.3	23	0329	2.5
	0749	1.4		0921	1.4
Sa	1407	2.6	Su	1509	2.6
	2049	1.0		2148	0.8
9	0259	2.4	24	0414	2.6
	0848	1.3		1007	1.3
Su	1455	2.7	M	1553	2.7
	2136	0.9		2228	0.7
10	0349	2.6	25	0453	2.6
	0939	1.2		1045	1.2
M	1540	2.9	T	1630	2.8
○	2221	0.7	●	2305	0.7
11	0438	2.7	26	0529	2.7
	1027	1.2		1118	1.2
T	1623	3.0	W	1702	2.8
	2304	0.5		2336	0.6
12	0527	2.8	27	0600	2.7
	1114	1.1		1149	1.2
W	1705	3.0	Th	1730	2.8
	2345	0.4			
13	0614	2.9	28	0004	0.6
	1200	1.1		0628	2.7
Th	1746	3.1	F	1218	1.2
				1757	2.8
14	0025	0.4	29	0030	0.7
	0659	2.9		0654	2.8
F	1246	1.2	Sa	1248	1.2
	1827	3.0		1826	2.7
15	0105	0.4	30	0054	0.7
	0741	3.0		0720	2.8
Sa	1333	1.2	Su	1320	1.2
	1910	2.9		1857	2.6
			31	0120	0.8
				0747	2.8
			M	1354	1.2
				1930	2.5

AUGUST

Day	Time	m	Day	Time	m
1	0147	1.0	16	0230	1.1
	0815	2.7		0854	2.7
T	1431	1.3	W	1525	1.2
	2007	2.3		2122	2.2
2	0219	1.2	17	0318	1.4
	0847	2.6		0940	2.4
W	1513	1.4	Th	1630	1.3
	2052	2.2		2258	2.1
3	0300	1.3	18	0443	1.6
	0929	2.5		1106	2.2
Th	1608	1.4	F	1820	1.3
	2200	2.1			
4	0404	1.5	19	0122	2.2
	1038	2.3		0722	1.6
F	1738	1.4	Sa	1308	2.2
				1956	1.2
5	0004	2.1	20	0237	2.3
	0555	1.6		0839	1.4
Sa	1229	2.3	Su	1424	2.3
	1920	1.3		2053	1.1
6	0141	2.2	21	0323	2.5
	0736	1.5		0925	1.3
Su	1347	2.4	M	1512	2.5
	2027	1.1		2136	0.9
7	0245	.4	22	0400	2.6
	0841	.3		1001	1.2
M	1441	2.6	T	1548	2.6
	2120	0.8		2210	0.8
8	0338	2.6	23	0433	2.7
	0935	1.2		1032	1.1
T	1528	2.8	W	1618	2.8
	2206	0.6		2241	0.7
9	0428	2.8	24	0502	2.8
	1022	1.0		1100	1.1
W	1611	3.0	Th	1644	2.8
○	2248	0.4	●	2308	0.6
10	0515	3.0	25	0529	2.8
	1107	1.0		1126	1.0
Th	1653	3.1	F	1710	2.8
	2327	0.3		2333	0.6
11	0557	3.1	26	0553	2.9
	1150	0.9		1152	1.0
F	1735	3.1	Sa	1737	2.8
				2356	0.6
12	0005	0.2	27	0615	2.9
	0637	3.2		1220	1.0
Sa	1232	0.9	Su	1805	2.7
	1816	3.0			
13	0041	0.3	28	0020	0.7
	0712	3.2		0638	2.9
Su	1313	0.9	M	1247	1.0
	1856	2.9		1834	2.6
14	0117	0.5	29	0044	0.8
	0745	3.1		0700	2.8
M	1354	1.0	T	1316	1.0
	1938	2.6		1903	2.5
15	0152	0.8	30	0109	1.0
	0818	2.9		0723	2.7
T	1438	1.1	W	1346	1.1
	2024	2.4		1935	2.4
			31	0139	1.2
				0750	2.6
			Th	1420	1.2
				2014	2.3

TACKLE CITY
107, Wisma Ganda, Tingkat Bawah,
Jalan Raja Omar, 32000 Sitiawan, Perak.
H/P\: 012-5300018, 016-593

016-52 5316

LUMUT, PERAK DARUL RIDZUAN

Lat 04 14 N Long 100 37 E

ZONE -0800 TIMES AND HEIGHTS OF HIGH AND LOW WATERS 2006

SEPTEMBER

Time	m	Day	Time	m
220	1.4	16 Sa	0500	1.8
826	2.4		1029	2.0
505	1.3		1752	1.5
113	2.1			
325	1.5	17 Su	0124	2.2
931	2.2		0748	1.6
624	1.4		1323	2.1
326	2.1		1940	1.3
536	1.6	18 M	0221	2.4
159	2.2		0838	1.4
849	1.4		1423	2.3
			2032	1.2
128	2.3	19 T	0258	2.6
736	1.5		0911	1.2
332	2.3		1459	2.5
007	1.1		2108	1.0
232	2.5	20 W	0330	2.8
337	1.3		0941	1.1
426	2.6		1529	2.6
058	0.8		2140	0.9
323	2.8	21 Th	0359	2.9
325	1.1		1008	1.0
512	2.8		1556	2.7
142	0.5		2208	0.8
108	3.0	22 F ●	0425	3.0
009	0.9		1035	0.9
555	3.0		1623	2.8
223	0.3		2233	0.7
50	3.2	23 Sa	0450	3.0
51	0.8		1100	0.9
38	3.1		1650	2.8
01	0.2		2257	0.7
27	3.3	24 Su	0512	3.0
32	0.7		1125	0.8
20	3.1		1717	2.8
38	0.3		2322	0.8
02	3.3	25 M	0535	3.0
10	0.6		1151	0.8
01	3.0		1746	2.7
			2347	0.9
13	0.4	26 T	0556	3.0
34	3.3		1217	0.8
48	0.7		1814	2.7
42	2.8			
48	0.7	27 W	0013	1.0
03	3.1		0619	2.9
24	0.8		1243	0.8
23	2.6		1843	2.6
23	1.0	28 Th	0041	1.1
52	2.8		0642	2.8
31	0.9		1310	1.0
07	2.4		1915	2.5
31	1.3	29 F	0114	1.3
13	2.6		0710	2.6
11	1.1		1343	1.1
12	2.2		1955	2.3
2	1.6	30 Sa	0156	1.5
4	2.3		0750	2.4
18	1.3		1431	1.3
3	2.1		2101	2.2

OCTOBER

Day	Time	m	Day	Time	m
1 Su	0313	1.7	16 M	0043	2.4
	0900	2.2		0727	1.6
	1554	1.4		1254	2.0
	2323	2.2		1850	1.5
2 M	0542	1.7	17 T	0138	2.5
	1129	2.1		0812	1.4
	1812	1.4		1353	2.2
				1946	1.3
3 T	0109	2.5	18 W	0217	2.7
	0726	1.5		0844	1.2
	1307	2.3		1430	2.4
	1931	1.1		2025	1.2
4 W	0208	2.8	19 Th	0249	2.9
	0823	1.2		0913	1.1
	1404	2.6		1501	2.5
	2023	0.8		2057	1.1
5 Th	0254	3.0	20 F	0317	3.0
	0908	1.0		0940	1.0
	1452	2.8		1530	2.6
	2106	0.6		2127	1.0
6 F	0337	3.2	21 Sa	0344	3.1
	0951	0.8		1007	0.9
	1537	2.9		1600	2.7
	2151	0.5		2155	0.9
7 Sa ○	0415	3.4	22 Su ●	0409	3.1
	1030	0.6		1032	0.8
	1622	3.0		1630	2.8
	2230	0.5		2224	0.9
8 Su	0451	3.4	23 M	0434	3.1
	1109	0.5		1059	0.7
	1706	3.0		1700	2.8
	2308	0.5		2253	1.0
9 M	0524	3.4	24 T	0459	3.1
	1146	0.5		1125	0.7
	1748	2.9		1731	2.7
	2347	0.7		2322	1.0
10 T	0555	3.2	25 W	0524	3.0
	1223	0.5		1153	0.7
	1829	2.8		1801	2.7
				2353	1.1
11 W	0023	1.0	26 Th	0551	2.9
	0624	3.0		1222	0.8
	1257	0.7		1833	2.6
	1910	2.6			
12 Th	0101	1.2	27 F	0024	1.3
	0653	2.8		0619	2.8
	1332	0.9		1253	0.9
	1954	2.5		1908	2.5
13 F	0143	1.5	28 Sa	0104	1.4
	0723	2.5		0653	2.6
	1410	1.1		1331	1.0
	2052	2.3		1958	2.4
14 Sa	0241	1.7	29 Su	0156	1.6
	0805	2.2		0738	2.4
	1502	1.4		1425	1.2
	2238	2.2		2117	2.4
15 Su	0523	1.8	30 M	0319	1.7
	0951	2.0		0850	2.3
	1653	1.5		1545	1.3
				2309	2.5
			31 T	0528	1.7
				1051	2.2
				1726	1.3

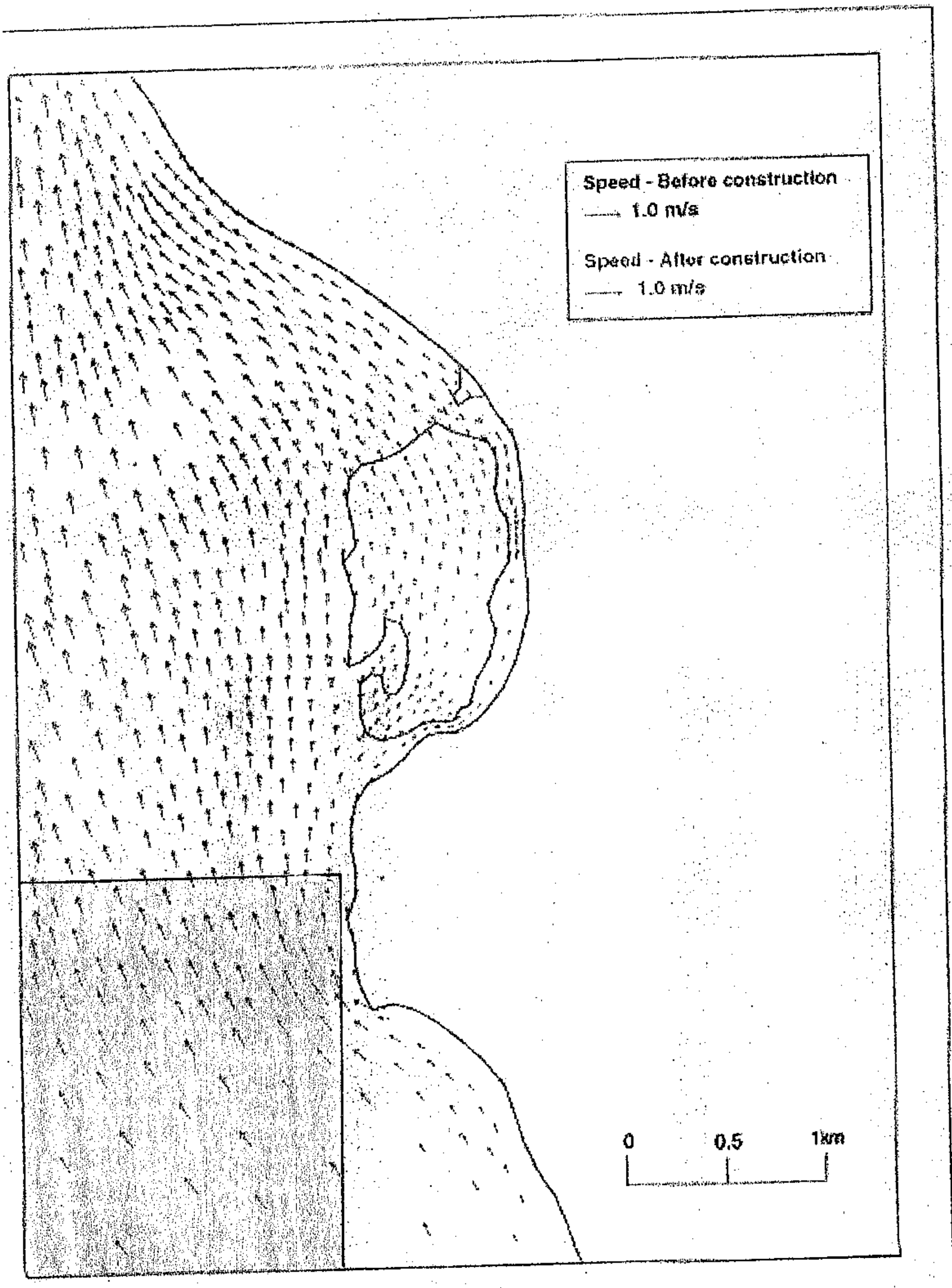
NOVEMBER

Day	Time	m	Day	Time	m
1 W	0034	2.7	16 Th	0118	2.7
	0700	1.5		0805	1.3
	1229	2.3		1346	2.2
	1843	1.1		1920	1.3
2 Th	0131	2.9	17 F	0156	2.8
	0758	1.2		0838	1.2
	1335	2.5		1427	2.3
	1941	0.9		2005	1.3
3 F	0218	3.2	18 Sa	0231	2.9
	0845	1.0		0908	1.0
	1429	2.7		1504	2.5
	2032	0.8		2045	1.2
4 Sa	0300	3.3	19 Su	0303	3.0
	0928	0.7		0937	0.8
	1520	2.8		1538	2.6
	2119	0.8		2123	1.1
5 Su	0339	3.4	20 M	0333	3.0
	1008	0.6		1006	0.7
	1608	2.9		1612	2.6
	2204	0.8		2158	1.1
6 M ○	0416	3.3	21 T ●	0404	3.0
	1047	0.4		1037	0.6
	1654	2.9		1647	2.7
	2246	0.9		2233	1.1
7 T	0452	3.3	22 W	0434	3.0
	1125	0.4		1108	0.6
	1738	2.8		1721	2.7
	2327	1.0		2307	1.1
8 W	0525	3.1	23 Th	0505	3.0
	1202	0.5		1140	0.6
	1822	2.7		1756	2.6
				2342	1.2
9 Th	0008	1.2	24 F	0537	2.9
	0558	2.9		1214	0.7
	1238	0.6		1835	2.6
	1904	2.6			
10 F	0049	1.4	25 Sa	0021	1.3
	0630	2.7		0611	2.8
	1314	0.8		1252	0.8
	1948	2.5		1919	2.6
11 Sa	0134	1.6	26 Su	0107	1.4
	0704	2.5		0650	2.7
	1353	1.1		1335	0.9
	2040	2.4		2013	2.5
12 Su	0232	1.7	27 M	0205	1.5
	0746	2.3		0737	2.5
	1438	1.3		1425	1.0
	2153	2.4		2122	2.6
13 M	0408	1.8	28 T	0319	1.6
	0858	2.1		0839	2.4
	1545	1.4		1525	1.0
	2323	2.4		2237	2.7
14 T	0514	1.7	29 W	0452	1.6
	1109	2.0		1008	2.2
	1712	1.5		1638	1.1
				2346	2.8
15 W	0031	2.6	30 Th	0620	1.4
	0723	1.5		1144	2.2
	1252	2.1		1752	1.1
	1825	1.4			

DECEMBER

Day	Time	m	Day	Time	m
1 F	0046	2.9	16 Sa	0053	2.6
	0726	1.2		0752	1.2
	1304	2.3		1347	2.1
	1857	1.1		1910	1.4
2 Sa	0138	3.0	17 Su	0143	2.6
	0820	0.9		0831	1.0
	1410	2.4		1437	2.2
	1959	1.1		2009	1.3
3 Su	0225	3.1	18 M	0226	2.7
	0907	0.7		0908	0.9
	1509	2.6		1518	2.4
	2056	1.0		2059	1.3
4 M	0309	3.1	19 T	0306	2.8
	0950	0.6		0944	0.7
	1602	2.7		1558	2.5
	2148	1.1		2142	1.2
5 T	0352	3.1	20 W ●	0343	2.8
	1031	0.5		1021	0.6
	1651	2.7		1638	2.6
	2237	1.1		2223	1.1
6 W ○	0431	3.0	21 Th	0420	2.9
	1111	0.4		1058	0.5
	1736	2.7		1718	2.6
	2321	1.2		2302	1.1
7 Th	0508	2.9	22 F	0455	2.9
	1150	0.5		1136	0.5
	1819	2.7		1759	2.6
				2342	1.1
8 F	0002	1.3	23 Sa	0531	2.9
	0544	2.8		1213	0.4
	1227	0.6		1842	2.7
	1858	2.6			
9 Sa	0042	1.4	24 Su	0025	1.2
	0618	2.7		0608	2.9
	1303	0.7		1252	0.5
	1938	2.6		1926	2.7
10 Su	0123	1.5	25 M	0112	1.3
	0652	2.6		0648	2.8
	1337	0.9		1331	0.5
	2018	2.5		2012	2.7
11 M	0208	1.5	26 T	0204	1.3
	0728	2.4		0731	2.6
	1411	1.0		1412	0.6
	2102	2.5		2101	2.8
12 T	0305	1.6	27 W	0302	1.4
	0813	2.2		0823	2.4
	1450	1.2		1458	0.8
	2153	2.5		2153	2.8
13 W	0418	1.6	28 Th	0409	1.4
	0916	2.0		0929	2.2
	1536	1.3		1552	[illegible]
	2252	2.5		2252	2.7
14 Th	0547	1.5	29 F	0529	1.3
	1048	1.9		1057	2.1
	1642	1.4		1659	1.1
	2355	2.6		2354	2.7
15 F	0701	1.4	30 Sa	0648	1.2
	1237	2.0		1235	2.1
	1759	1.4		1816	1.2
			31 Su	0100	2.7
				0755	1.0
				1403	2.2
				1940	1.3

Tidal Current For Ebb

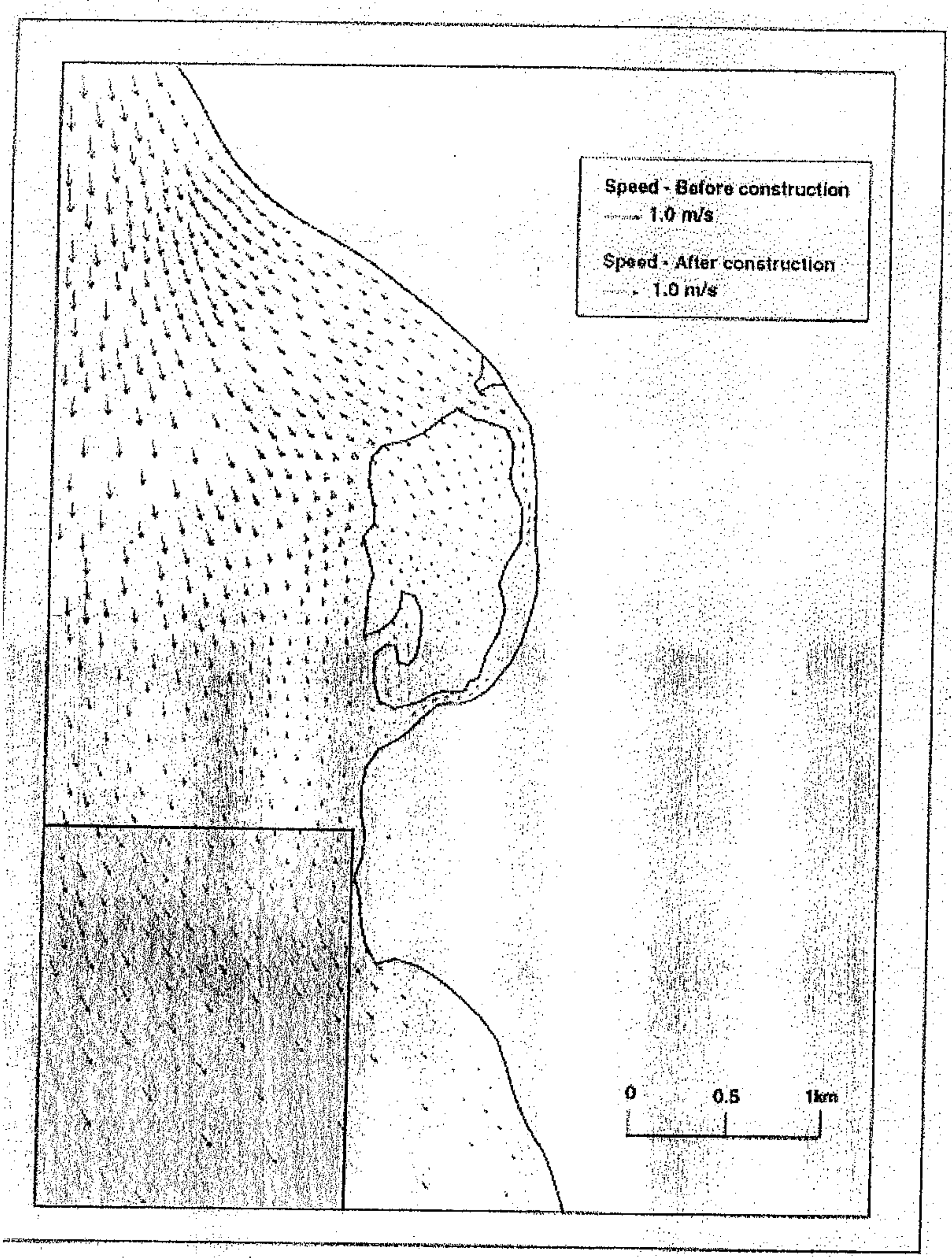


igure 3.7b Simulated spring tide flow patterns - peak northward flow, before and after the reclamation construction

NOTE:

Selected Area

Tidal Current For Flood



igure 3.7a Simulated spring tide flow patterns - peak southward flow, before and after the reclamation construction

NOTE:

Selected Area

Tidal Current Data for Ebb Flow

Simulated spring tide flow patterns - peak northward flow, after the reclamation construction (Ebb flow)

Current direction = 335 Degrees

Arrow	Current speed (m/s)	Arrow	Current speed (m/s)
1	0.5385	44	0.4615
2	0.4615	45	0.4615
3	0.5385	46	0.4615
4	0.4615	47	0.4615
5	0.4615	48	0.4615
6	0.4615	49	0.4615
7	0.4615	50	0.4615
8	0.5385	51	0.4615
9	0.4615	52	0.4615
10	0.4615	53	0.4615
11	0.4615	54	0.4615
12	0.4615	55	0.4615
13	0.4615	56	0.4615
14	0.4615	57	0.4615
15	0.4615	58	0.4615
16	0.4615	59	0.4615
17	0.4615	60	0.4615
18	0.4615	61	0.4615
19	0.4615	62	0.4615
20	0.4615	63	0.4615
21	0.4615	64	0.4615
22	0.4615	65	0.4615
23	0.4615	66	0.4615
24	0.4615	67	0.4615
25	0.4615	68	0.4615
26	0.4615	69	0.4615
27	0.4615	**Total**	**31.7669**
28	0.4615		
29	0.4615		
30	0.4615		
31	0.4615		
32	0.4615		
33	0.4615		
34	0.4615		
35	0.4615		
36	0.4615		
37	0.4615		
38	0.4615		
39	0.4615		
40	0.4615		
41	0.3077		
42	0.3077		
43	0.4615		

$$V_{avg} = \frac{V_{Total}}{N_{Aarows}}$$

$$V_{avg} = \frac{31.7669}{69}$$

$$V_{avg} = 0.4604 \mathrm{m/s}$$

Tidal Current Data for Flood Flow

Simulated spring tide flow patterns - peak southward flow, after the reclamation construction (Flood flow)

Current direction = 145 Degrees

Arrow	Current speed (m/s)	Arrow	Current speed (m/s)
1	0.5385	44	0.4612
2	0.5385	45	0.4612
3	0.4612	46	0.4612
4	0.4612	47	0.4612
5	0.4612	48	0.4612
6	0.4612	49	0.4612
7	0.4612	50	0.4612
8	0.4612	51	0.4612
9	0.4612	52	0.4612
10	0.5385	53	0.4612
11	0.4612	54	0.4612
12	0.4612	55	0.4612
13	0.3077	56	0.4612
14	0.4612	57	0.4612
15	0.4612	58	0.4612
16	0.4612	59	0.4612
17	0.4612	60	0.4612
18	0.4612	Total	27.7504
19	0.4612		
20	0.4612		
21	0.4612		
22	0.4612		
23	0.4612		
24	0.4612		
25	0.4612		
26	0.4612		
27	0.4612		
28	0.4612		
29	0.4612		
30	0.4612		
31	0.4612		
32	0.4612		
33	0.4612		
34	0.4612		
35	0.4612		
36	0.4612		
37	0.4612		
38	0.4612		
39	0.4612		
40	0.4612		
41	0.4612		
42	0.4612		
43	0.4612		

$$V_{avg} = \frac{V_{Total}}{N_{Aarows}}$$

$$V_{avg} = \frac{27.7504}{60}$$

$$V_{avg} = 0.4625 m/s$$

Monthly Maximum Surface Wind

PERKHIDMATAN KAJICUACA MALAYSIA

Records of Monthly Maximum Surface Wind

Unit : direction in degree / speed in metre per second

Station : Sitiawan
Lat . : 04 ° 13 ' N
Long. : 100 ° 42 ' E
Ht. of Anemometer Head Above Ground : 16.8 m

Month / Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Extreme
1968	240/12.4	210/12.0	320/16.4	200/11.5 270/11.5	260/21.5	350/13.1	320/13.9	270/17.5	340/14.3	300/13.6	140/19.2	220/14.7	260/21.5
1969	230/11.7	040/14.2	050/16.1	050/14.5	200/15.8	300/14.5	230/19.0	190/16.1	330/15.1	260/15.1	210/14.4	080/12.2	230/19.0
1970	050/13.2	300/11.6	090/11.9	100/28.0	300/15.1	250/15.7	130/18.4	240/15.6	330/16.8	280/14.9	220/11.6	300/11.5	100/28.0
1971	230/11.3	130/15.0	340/13.1	120/18.0	330/14.6	360/16.4	250/18.0	080/21.2	350/15.5	210/15.0	360/14.5	350/13.5	080/21.2
1972	320/11.9	290/12.2	030/13.5 360/13.5	230/14.5	120/19.2	130/13.5	180/16.4	180/16.5	290/14.5	090/13.7	300/17.0	030/13.3	120/19.2
1973	160/13.7	190/12.9 320/12.9	310/18.9	220/16.0	020/15.5	200/16.2	240/19.3 330/19.3	180/15.8	260/15.0	290/14.7	270/13.3	200/17.0	240/19.3 330/19.3
1974	180/11.2	030/13.5	080/13.8	190/14.4	340/17.1	210/16.9	200/12.5 300/12.5	290/14.6	270/14.0	180/15.0	310/14.1	280/12.4	340/17.1
1975	190/11.6	240/11.8	020/15.1	360/17.2	360/15.5	300/19.0	230/14.9	220/15.4	230/14.7	190/14.4	010/13.5	340/12.1	300/19.0
1976	N.A.	270/12.6	280/14.0	030/13.5	270/16.1	180/15.0	320/20.0	330/15.6	310/16.6	280/18.5	270/13.0	300/11.3	N.A.
1977	120/11.5 240/11.5	030/14.2	040/15.3	120/22.4	330/12.9	240/14.1	220/16.0	280/14.2	250/14.9	230/13.9	050/14.6 090/14.6	190/16.5	120/22.4
1978	360/13.4	350/14.6	020/12.6	110/13.3	200/12.1	220/12.7	280/13.5	250/18.0	320/13.2	310/12.6	310/14.5	360/19.8	360/19.8
1979	070/10.7	360/17.7	210/12.1	130/16.8	210/15.3	220/17.7	290/15.2	220/14.5	190/14.0	300/14.4	210/16.1	090/11.0	220/17.7 360/17.7
1980	250/13.8	210/13.7	250/14.6	280/13.2	210/13.7	200/13.9 210/13.9	270/15.2	270/17.5	220/15.8	310/13.0	100/14.7	330/14.4	270/17.5
1981	310/13.1	090/16.6	040/14.0	100/16.0	170/14.6	200/12.1	180/14.7	260/16.5	250/17.4	230/15.7	320/14.6	050/11.2	250/17.4
1982	060/12.6	050/19.5	310/12.0	120/15.1	180/16.4	200/15.5	230/27.6	240/21.0	090/13.9	300/14.7	150/11.2	080/12.7	230/27.6
1983	270/11.1	070/12.0	210/12.5	290/10.9	040/12.2	010/14.3	210/13.0	240/13.5	210/17.3	310/13.5	320/11.8	240/12.8	210/17.3
1984	320/13.2	330/13.9	080/16.1	040/14.3	220/11.7	200/21.1	060/13.8	190/10.6 200/10.6	330/14.5	340/17.5	160/13.5	340/10.6	200/21.1
1985	100/9.8	060/13.1	020/14.7	320/13.9	170/12.7	310/10.6	260/10.7	210/12.5	260/15.3	330/13.4	040/13.5	200/8.8	260/15.3
1986	170/9.5	260/11.2	210/11.8	080/10.4	270/17.6	180/12.3	270/16.0	200/12.5	270/15.6	210/12.7	270/13.1	360/12.7	270/17.6
1987	040/10.0	200/11.5	230/12.7	070/16.4	310/12.7	190/12.3	290/14.0	360/14.8	300/16.0	070/12.4	280/14.6	320/14.9	070/16.4
1988	010/14.4	010/13.3 070/13.3	050/13.9	150/14.4	310/12.3	320/14.9	260/18.7 300/18.7	220/12.7	320/12.7	240/15.1	200/12.4	030/10.4	260/18.7 300/18.7
1989	050/13.1	110/11.0	050/13.0	320/12.1	310/14.0	340/12.0	190/11.6	210/15.5	290/16.2	240/12.7	070/20.5	280/9.8	070/20.5
1990	220/9.9	130/12.6	220/10.2	220/16.9	320/14.6	210/17.4	280/14.9	N.A.	260/14.6	050/14.0	320/15.1	350/13.1	N.A.
1991	040/12.9	060/15.8	080/12.5	200/12.9	060/13.1	190/13.0	140/13.7	310/14.1	270/15.1	130/11.6	220/12.4	260/11.7	060/15.8
1992	270/10.9	080/14.3	220/10.0	200/12.7	200/19.3	250/14.9	210/12.3	340/15.5	200/13.5	320/14.1	020/10.6	070/12.0	200/19.3
1993	040/12.8	030/15.0	350/12.9	340/15.6	200/12.4	N.A.	010/14.5	240/14.5	200/13.7	320/12.4	230/11.0	290/13.5	N.A.
1994	350/12.0	320/11.4	070/14.9	320/13.0	270/12.9	030/14.4 250/14.4	290/15.4	190/13.9	200/14.6	170/13.5	360/12.1	100/10.7	290/15.4
1995	040/14.8	090/13.6	260/13.0	110/13.7	210/14.8	320/11.6	200/13.4	250/13.1	320/15.5	320/15.5	110/11.9	040/16.1	040/16.1
1996	350/11.5	070/12.6	060/18.6	300/12.6	200/12.1	240/18.3	180/11.6 190/11.6	290/17.0	350/13.5	200/13.1	270/15.3	320/12.0	060/18.6
1997	080/11.5	290/11.9	250/13.2	060/17.5	220/11.5	210/14.7	200/13.0	290/18.4	050/13.5	200/12.0	160/12.1	160/15.6	290/18.4
1998	150/13.7	280/10.9	240/12.7	090/10.9	100/16.7	220/14.3	320/12.1	230/12.3	250/12.9	300/16.3	230/15.2	050/21.6	050/21.6
1999	020/12.1	330/13.1	290/13.4	220/11.5 290/11.5	210/10.5 230/10.5	280/12.4	350/13.2	350/13.2	N.A.	260/14.3	020/24.6	280/11.0	N.A.
2000	360/14.0	280/12.4	270/11.2	330/16.6	260/16.3	300/17.8	200/16.0	170/15.6	180/14.6	330/15.7	340/13.0	060/9.6	300/17.8
2001	020/13.8	340/13.7	070/13.7	210/14.0	210/12.0	290/12.1	260/12.5	270/16.5	210/13.1	350/17.3	280/12.3	030/13.4	350/17.3
2002	060/13.7	090/13.5	340/14.0	150/17.0	100/12.5	330/11.8	270/14.8	360/16.0	360/16.1	200/12.5	320/13.8	110/16.5	150/17.0
2003	310/16.0	080/12.4	090/12.4	160/13.1	200/13.0	N.A.	180/10.7	270/12.9	220/10.5	220/17.2	130/10.2	030/8.1	N.A.
2004	220/7.5	210/8.9	290/8.0 300/8.0	090/10.6	N.A.	330/12.5	230/13.0	170/12.5 290/12.5	170/12.0	320/14.5	220/10.4	330/14.0	N.A.
2005	260/9.6	210/9.4	060/11.3	N.A.	260/12.0	240/13.8	310/10.4	290/16.4	300/10.8	340/11.6	220/10.7	290/13.3	N.A.

Note : N.A. - Not Available
Sev. - Several Occasions

Annual Wind Rose

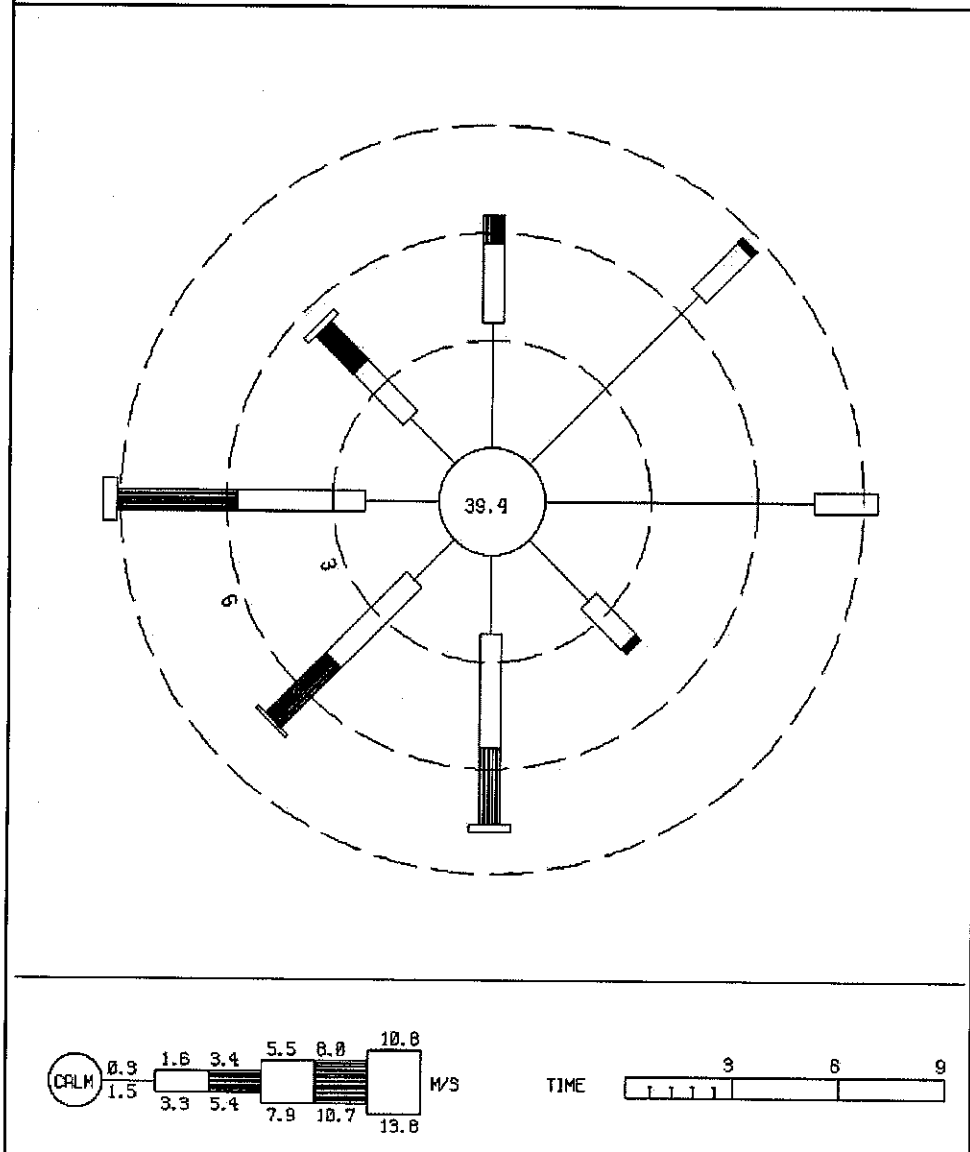
WIND ROSE SUMMARY

SITIAWAN

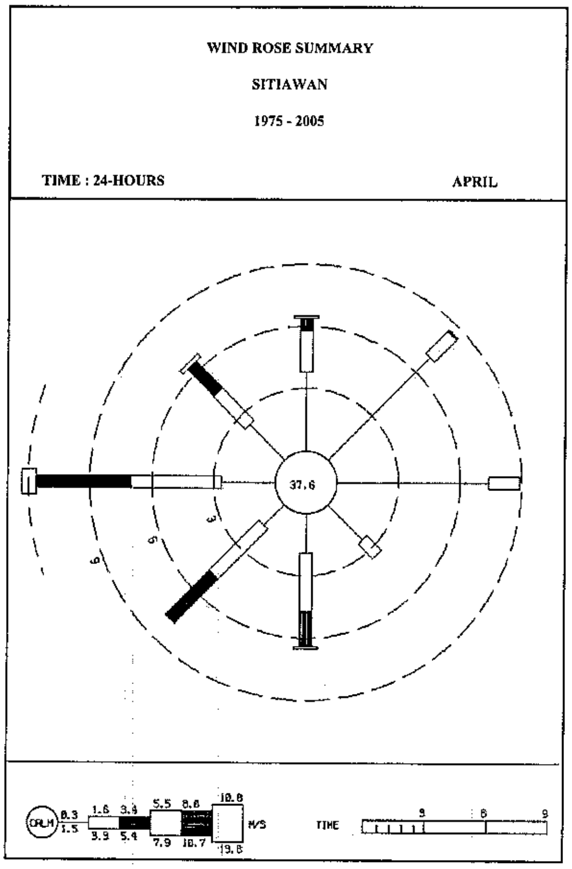
1975 - 2005

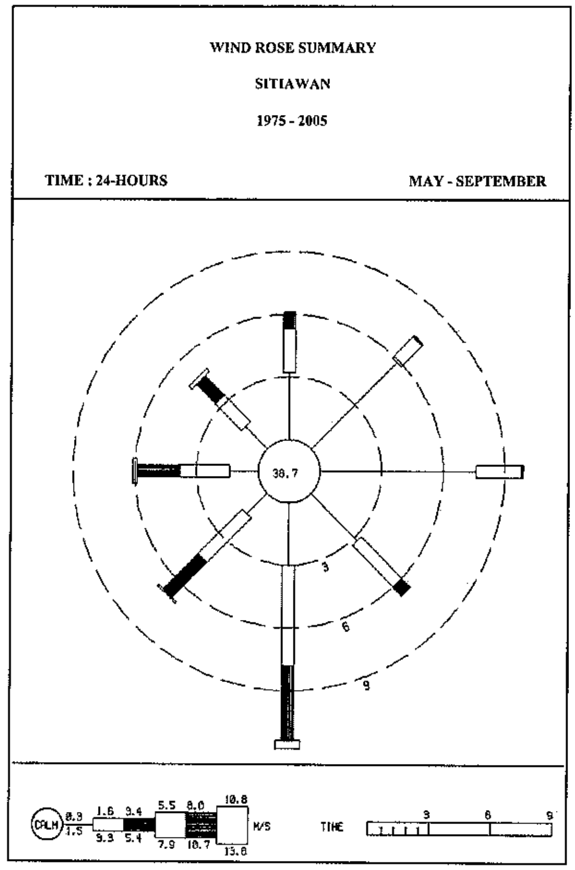
TIME : 24-HOURS

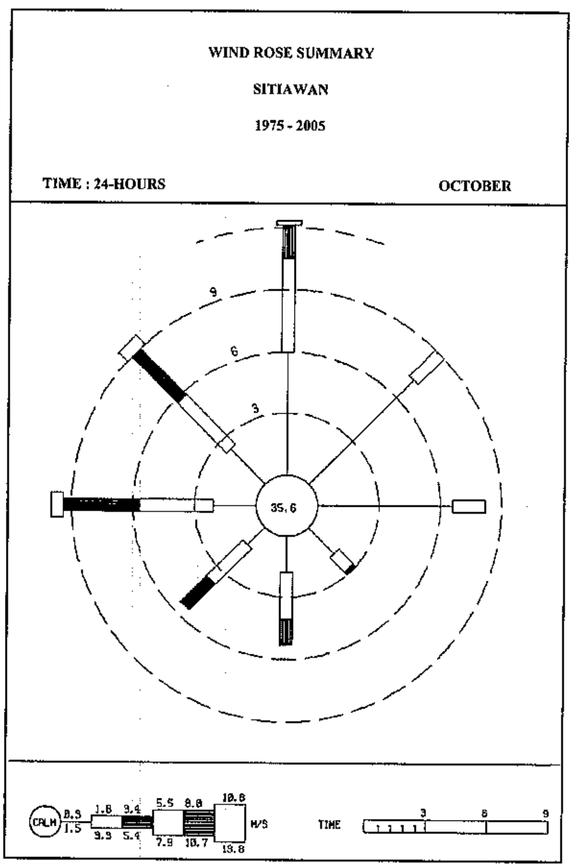
ANNUAL

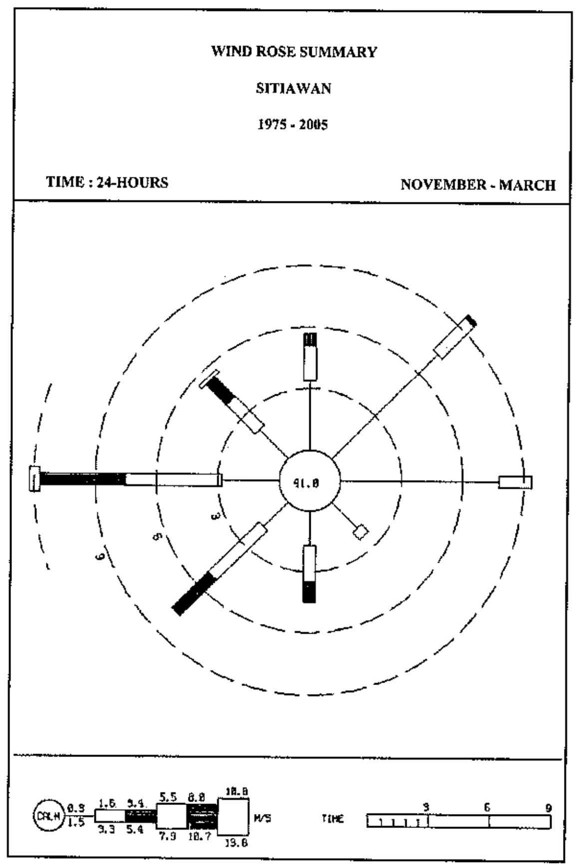


Seasonal Wind Rose









PERCENTAGE FREQUENCY OF VARIOUS DIRECTIONS AND SPEEDS

STATION : SITIAWAN

PERIOD : 1975 - 2005
TIME : ALL 24 HOURS

SPEED M/S	N	NE	E	SE	S	SW	W	NW	CALM	TOTAL
					APRIL					
< 0.3	-	-	-	-	-	-	-	-	37.6	37.6
0.3 - 1.5	3.8	7.0	7.4	2.4	1.9	1.4	2.6	2.4	-	28.9
1.6 - 3.3	2.0	1.5	1.5	1.0	2.8	3.4	4.4	2.2	-	18.8
3.4 - 5.4	0.6	0.1	0.0	0.0	1.7	3.0	4.6	1.8	-	11.8
5.5 - 7.9	0.1	0.0	0.0	0.0	0.1	0.0	0.7	0.2	-	1.1
8.0 - 10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
> 10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
TOTAL	6.5	8.6	8.9	3.4	6.5	7.8	12.3	6.6	37.6	

SPEED M/S	N	NE	E	SE	S	SW	W	NW	CALM	TOTAL
					MAY - SEPTEMBER					
< 0.3	-	-	-	-	-	-	-	-	38.7	38.7
0.3 - 1.5	3.2	5.9	7.6	3.2	3.0	1.4	1.4	1.5	-	27.2
1.6 - 3.3	2.1	1.4	2.2	2.8	4.8	3.0	2.4	1.8	-	20.5
3.4 - 5.4	0.8	0.1	0.1	0.6	3.6	2.4	2.1	1.3	-	11.0
5.5 - 7.9	0.0	0.0	0.0	0.0	0.4	0.1	0.2	0.2	-	0.9
8.0 - 10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
> 10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
TOTAL	6.1	7.4	9.9	6.6	11.8	6.9	6.1	4.8	38.7	

SPEED M/S	N	NE	E	SE	S	SW	W	NW	CALM	TOTAL
					OCTOBER					
< 0.3	-	-	-	-	-	-	-	-	35.6	35.6
0.3 - 1.5	6.0	7.2	6.6	1.8	1.8	1.2	2.1	2.4	-	29.1
1.6 - 3.3	4.5	1.8	1.6	1.0	2.3	2.5	3.6	3.4	-	20.7
3.4 - 5.4	1.6	0.0	0.0	0.2	1.2	1.8	3.7	3.2	-	11.7
5.5 - 7.9	0.2	0.0	0.0	0.0	0.0	0.0	0.6	0.6	-	1.4
8.0 - 10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
> 10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
TOTAL	12.3	9.0	8.2	3.0	5.3	5.5	10.0	9.6	35.6	

SPEED M/S	N	NE	E	SE	S	SW	W	NW	CALM	TOTAL
					NOVEMBER - MARCH					
< 0.3	-	-	-	-	-	-	-	-	41.0	41.0
0.3 - 1.5	3.4	7.3	7.8	1.8	1.7	1.7	2.8	2.0	-	28.5
1.6 - 3.3	1.7	2.2	1.6	0.5	1.8	3.5	4.7	2.0	-	18.0
3.4 - 5.4	0.6	0.2	0.0	0.0	1.0	2.5	4.2	1.4	-	9.9
5.5 - 7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.2	-	0.7
8.0 - 10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
> 10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
TOTAL	5.7	9.7	9.4	2.3	4.5	7.7	12.2	5.6	41.0	

SPEED M/S	N	NE	E	SE	S	SW	W	NW	CALM	TOTAL
					ANNUAL					
< 0.3	-	-	-	-	-	-	-	-	39.4	39.4
0.3 - 1.5	3.5	6.7	7.6	2.4	2.2	1.6	2.1	1.8	-	27.9
1.6 - 3.3	2.2	1.8	1.8	1.6	3.2	3.2	3.6	2.0	-	19.4
3.4 - 5.4	0.8	0.2	0.0	0.2	2.2	2.4	3.4	1.5	-	10.7
5.5 - 7.9	0.0	0.0	0.0	0.0	0.2	0.1	0.4	0.2	-	0.9
8.0 - 10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
> 10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-	0.0
TOTAL	6.5	8.7	9.4	4.2	7.8	7.3	9.5	5.5	39.4	

Wave Statistics Summaries of Annual Period

Appendix 3-13(a)

BAHAGIAN KEJURUTERAAN PANTAI
JABATAN PENGAIRAN DAN SALIRAN MALAYSIA
WAVE STATISTICS SUMMARIES - WAVE & SWELL
(ANNUAL PERIOD)

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
STARTING DATE : 01-01-1948 ENDING DATE : 31-12-1984
NO. OBSERVATIONS : 5000 PERCENT CALM : 0.00%
CHOSEN MONTHS : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Direction : 135 - 165 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	5.7	0.2	0.1	0	0	0.1	6
0.75 - 1.25	2.7	0.3	0.1	0	0	0.1	3.2
1.25 - 1.75	0.7	0.1	0	0	0	0.1	0.9
1.75 - 2.25	0.2	0.1	0	0	0	0	0.3
2.25 - 2.75	0.1	0	0	0	0	0	0.1
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0.1	0	0	0	0	0	0.1
Total	9.4	0.7	0.2	0.1	0.1	0.2	10.6

Direction : 165 - 195 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	4.5	0.1	0	0	0	0	4.7
0.75 - 1.25	1.1	0.2	0.1	0	0	0.1	1.5
1.25 - 1.75	0.2	0.1	0	0	0	0	0.3
1.75 - 2.25	0.1	0	0	0	0	0	0.1
2.25 - 2.75	0	0.1	0	0	0	0	0.1
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0
Total	5.9	0.5	0.1	0.1	0.1	0.1	6.8

Direction : 195 - 225 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	3.3	0.1	0.1	0	0	0	3.5
0.75 - 1.25	0.6	0.2	0	0	0	0.1	0.9
1.25 - 1.75	0.2	0	0	0	0	0	0.2
1.75 - 2.25	0.1	0	0	0	0	0	0.2
2.25 - 2.75	0	0	0	0	0	0	0
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0.1	0.1
Total	4.2	0.4	0.2	0	0	0.2	5

Direction : 225 - 255 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	2.7	0.1	0	0	0	0	2.9
0.75 - 1.25	0.9	0.1	0	0	0	0	1.1
1.25 - 1.75	0.1	0	0	0	0	0	0.2
1.75 - 2.25	0	0.1	0	0	0	0	0.1
2.25 - 2.75	0	0	0	0	0	0	0
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0
Total	3.8	0.5	0.1	0.1	0	0	4.4

Wave Statistics Summaries of Annual Period

Appendix 3-13(b)

Direction : 255 - 285 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	5.3	0.1	0	0	0	0	5.5
0.75 - 1.25	1.7	0.4	0.1	0	0	0.1	2.3
1.25 - 1.75	0.3	0.2	0	0	0	0	0.6
1.75 - 2.25	0.1	0.1	0.1	0	0	0	0.3
2.25 - 2.75	0	0	0	0	0	0	0.1
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0
Total	7.4	0.9	0.2	0.1	0	0.2	8.8

Direction : 285 - 315 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	7.8	0.4	0.1	0.1	0	0.1	8.5
0.75 - 1.25	4.4	0.6	0.1	0.1	0	0.2	5.4
1.25 - 1.75	1	0.4	0.1	0	0	0.1	1.7
1.75 - 2.25	0.2	0.3	0	0	0	0	0.6
2.25 - 2.75	0.1	0.1	0	0	0	0	0.2
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0.1
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0.1
Total	13.6	1.8	0.4	0.2	0.1	0.5	16.6

Direction : 315 - 345 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	7.4	0.3	0.1	0.1	0	0.2	8.1
0.75 - 1.25	4	0.8	0.1	0.1	0	0.2	5.2
1.25 - 1.75	1	0.3	0.1	0	0	0	1.5
1.75 - 2.25	0.1	0.1	0	0	0	0	0.3
2.25 - 2.75	0	0.1	0	0	0	0	0.2
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0.1
Total	12.7	1.6	0.3	0.2	0	0.4	15.3

Reference	: Mars2627.dbf
Processed by	: zanal Abidin Hj. Ismail
Date Processed	: 07-03-2006
Fax Number	: 03-26936625
Tel Number	: 03-26972043
e-mail Address	: zanal@water.gov.my

Wave Statistics Summaries of North-East Monsoon

Appendix 3-14(a)

BAHAGIAN KEJURUTERAAN PANTAI
JABATAN PENGAIRAN DAN SALIRAN MALAYSIA
WAVE STATISTICS SUMMARIES - WAVE & SWELL
(NORTH-EAST MONSOON)

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
STARTING DATE : 01-01-1948 ENDING DATE : 31-12-1984
NO. OBSERVATIONS : 2587 PERCENT CALM : 0.00%
CHOSEN MONTHS : JAN FEB MAC APR NOV DEC

Direction : 135 - 165 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	3.7	0.2	0.1	0	0	0	3.9
0.75 - 1.25	1.4	0.1	0	0	0	0	1.6
1.25 - 1.75	0.2	0	0	0	0	0	0.2
1.75 - 2.25	0	0	0	0	0	0	0
2.25 - 2.75	0	0	0	0	0	0	0
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0
Total	5.3	0.3	0.1	0.1	0	0	5.9

Direction : 165 - 195 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	3.8	0.1	0	0.1	0	0	4
0.75 - 1.25	0.9	0.1	0	0	0	0	1.1
1.25 - 1.75	0	0.1	0	0	0	0	0.2
1.75 - 2.25	0	0	0	0	0	0	0
2.25 - 2.75	0	0	0	0	0	0	0
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0
Total	4.8	0.3	0	0.2	0	0	5.3

Direction : 195 - 225 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	3.2	0.2	0.1	0	0	0	3.5
0.75 - 1.25	0.7	0.2	0	0	0	0.1	1
1.25 - 1.75	0.1	0	0	0	0	0	0.1
1.75 - 2.25	0.1	0	0	0	0	0	0.1
2.25 - 2.75	0	0	0	0	0	0	0
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0.1	0.1
Total	4.1	0.4	0.2	0	0	0.2	4.8

Direction : 225 - 255 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	3.2	0	0	0	0	0	3.3
0.75 - 1.25	0.9	0.2	0	0	0	0	1.1
1.25 - 1.75	0.1	0	0	0	0	0	0.1
1.75 - 2.25	0	0	0	0	0	0	0.1
2.25 - 2.75	0	0	0	0	0	0	0
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0
Total	4.2	0.2	0.1	0.1	0	0	4.6

Wave Statistics Summaries of North-East Monsoon

Appendix 3-14(b)

Direction : 255 - 285 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	6.8	0.1	0	0	0	0	7
0.75 - 1.25	1.7	0.2	0	0	0	0	2
1.25 - 1.75	0.3	0.1	0	0	0	0	0.3
1.75 - 2.25	0	0	0.1	0	0	0	0.2
2.25 - 2.75	0	0	0	0	0	0	0.1
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0
Total	8.9	0.4	0.2	0.1	0	0.1	9.6

Direction : 285 - 315 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	9.1	0.2	0	0.1	0	0.1	9.6
0.75 - 1.25	4.4	0.3	0.1	0	0	0.2	5.1
1.25 - 1.75	0.9	0.1	0.1	0	0	0	1
1.75 - 2.25	0.2	0.2	0	0	0	0	0.3
2.25 - 2.75	0.1	0	0	0	0	0	0.1
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0.1
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0.1
Total	14.7	0.9	0.2	0.2	0.1	0.4	16.4

Direction : 315 - 345 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	8.5	0.2	0.1	0.1	0	0.2	9.2
0.75 - 1.25	3.7	0.7	0.1	0.1	0	0.1	4.7
1.25 - 1.75	0.8	0.2	0	0	0	0	1.1
1.75 - 2.25	0.2	0	0	0	0	0	0.3
2.25 - 2.75	0.1	0	0	0	0	0	0.1
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0.1
Total	13.4	1.2	0.3	0.3	0	0.3	15.5

Reference : Mars2627.dbf
Processed by : zanal Abidin Hj. Ismail
Date Processed : 07-03-2006
Fax Number : 03-26936625
Tel Number : 03-26972043
e-mail Address : zanal@water.gov.my

Wave Statistics Summaries of South-East Monsoon

Appendix 3-15(a)

BAHAGIAN KEJURUTERAAN PANTAI
JABATAN PENGAIRAN DAN SALIRAN MALAYSIA
WAVE STATISTICS SUMMARIES - WAVE & SWELL
(SOUTH-WEST MONSOON)

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
STARTING DATE : 01-01-1948 ENDING DATE : 31-12-1984
NO. OBSERVATIONS : 2413 PERCENT CALM : 0.00%
CHOSEN MONTHS : MAY JUN JUL AUG SEP OCT

Direction : 135 - 165 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	7.9	0.2	0	0	0	0.1	8.2
0.75 - 1.25	4.1	0.4	0.2	0	0.1	0.2	5
1.25 - 1.75	1.2	0.2	0	0	0	0.1	1.7
1.75 - 2.25	0.4	0.1	0	0	0	0	0.5
2.25 - 2.75	0.1	0	0	0	0	0	0.1
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0.1	0	0	0	0	0	0.1
Total	3.8	1	0.2	0.1	0.1	0.4	15.7

Direction : 165 - 195 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	5.2	0.2	0	0	0	0.1	5.5
0.75 - 1.25	1.3	0.3	0.1	0	0	0.1	1.9
1.25 - 1.75	0.4	0	0	0	0	0	0.5
1.75 - 2.25	0.2	0	0	0	0	0	0.2
2.25 - 2.75	0	0.1	0	0	0	0	0.1
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0
Total	7.1	0.7	0.2	0	0.1	0.2	8.5

Direction : 195 - 225 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	3.4	0	0.1	0	0	0	3.6
0.75 - 1.25	0.5	0.2	0	0	0	0.2	0.9
1.25 - 1.75	0.2	0	0	0	0	0	0.4
1.75 - 2.25	0.2	0	0	0	0	0	0.2
2.25 - 2.75	0	0	0	0	0	0	0
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0.1
Total	4.3	0.3	0.2	0	0	0.2	5.2

Direction : 225 - 255 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	2.2	0.2	0	0	0	0	2.5
0.75 - 1.25	1	0.1	0	0	0	0	1.1
1.25 - 1.75	0.2	0.1	0	0	0	0	0.3
1.75 - 2.25	0	0.2	0	0	0	0	0.2
2.25 - 2.75	0	0	0	0	0	0	0
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0
Total	3.4	0.7	0.1	0	0	0	4.3

Wave Statistics Summaries of South-East Monsoon

Appendix 3-15(b)

Direction : 255 - 285 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	3.6	0.2	0	0	0	0	3.9
0.75 - 1.25	1.7	0.7	0.1	0	0	0.2	2.7
1.25 - 1.75	0.4	0.3	0.1	0	0	0	0.8
1.75 - 2.25	0.2	0.2	0	0	0	0	0.5
2.25 - 2.75	0	0	0	0	0	0	0
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0
Total	5.9	1.3	0.2	0.1	0	0.3	7.8

Direction : 285 - 315 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	6.4	0.5	0.2	0.1	0.1	0.1	7.4
0.75 - 1.25	4.4	0.9	0.2	0.1	0	0.2	5.8
1.25 - 1.75	1.1	0.8	0.2	0	0	0.2	2.3
1.75 - 2.25	0.3	0.5	0	0	0.1	0	0.8
2.25 - 2.75	0.2	0.1	0	0	0	0	0.3
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0.1	0	0.1	0.2
Total	12.4	2.8	0.6	0.3	0.2	0.6	16.9

Direction : 315 - 345 DEGREES

Wave Height (meters)	Period (seconds)						Total
	4.0 - 5.0	6.0 - 7.0	8.0 - 9.0	10.0 - 11.0	12.0 - 13.0	> 13.0	
< 0.75	6.2	0.5	0	0	0	0.1	6.8
0.75 - 1.25	4.3	0.9	0.1	0.1	0	0.3	5.7
1.25 - 1.75	1.3	0.4	0.2	0	0	0	1.9
1.75 - 2.25	0	0.2	0	0	0	0	0.3
2.25 - 2.75	0	0.2	0	0	0	0	0.2
2.75 - 3.25	0	0	0	0	0	0	0
3.25 - 3.75	0	0	0	0	0	0	0
3.75 - 4.25	0	0	0	0	0	0	0
> 4.25	0	0	0	0	0	0	0
Total	11.9	2.1	0.4	0.1	0	0.5	15

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BAHAGIAN KEJURUTERAAN PANTAI
JABATAN PENGAIRAN DAN SALIRAN MALAYSIA
WAVE STATISTICS
MAXIMUM WAVE HEIGHT

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 150 [135 - 165 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

YEAR	MAXIMUM WAVE HEIGHT METERS					WAVE PERIOD SECONDS				
	1	2	3	4	5	1	2	3	4	5
1949	1	1	0.5	0.5	0.5	4.5	4.5	8.5	6.5	4.5
1950	1	0.5	0.5	0.5	0.5	6.5	4.5	4.5	4.5	4.5
1951	1	0.5	0.5	0.5	-	10.5	6.5	4.5	4.5	-
1952	1	0.5	0.5	0.5	-	6.5	4.5	4.5	4.5	-
1953	1.5	1	1	0.5	0.5	16.5	4.5	4.5	4.5	4.5
1954	1	1	1	1	1	8.5	4.5	4.5	4.5	4.5
1955	0.5	0.5	-	-	-	4.5	4.5	-	-	-
1956	1.5	1	0.5	-	-	4.5	8.5	4.5	-	-
1957	1.5	1	1	0.5	0.5	8.5	4.5	4.5	4.5	4.5
1958	0.5	0.5	-	-	-	4.5	4.5	-	-	-
1959	1.5	1	1	0.5	-	6.5	4.5	4.5	4.5	-
1960	1	1	1	1	0.5	6.5	4.5	4.5	4.5	4.5
1961	1	1	1	0.5	-	4.5	4.5	4.5	4.5	-
1962	1	-	-	-	-	6.5	-	-	-	-
1963	1	0.5	0.5	0.5	0.5	4.5	4.5	4.5	4.5	4.5
1964	1	1	1	1	0.5	4.5	4.5	4.5	4.5	6.5
1965	1	1	1	1	0.5	12.5	4.5	4.5	4.5	4.5
1966	1	1	1	0.5	0.5	6.5	4.5	4.5	6.5	4.5
1967	2	1.5	1.5	1	1	4.5	6.5	6.5	6.5	4.5
1968	0.5	-	-	-	-	4.5	-	-	-	-
1969	1.5	1.5	1	1	1	4.5	4.5	4.5	4.5	4.5
1971	1.5	1.5	1.5	1	1	14	13	6	4.5	4.5
1972	2	2	2	1.5	1.5	6	4.5	4.5	4.5	4.5
1973	2	1.5	1.5	0.5	0.5	4.5	10	4.5	8	8
1974	1	1	0.5	0.5	0.5	6.5	4.5	4.5	4.5	4.5
1975	1.5	1	0.5	0.5	0.5	4.5	4.5	4.5	4.5	4.5
1976	2	1.5	1	1	1	6.5	4.5	12	9	4.5
1977	2	1.5	1.5	1.5	1.5	7	4.5	4.5	4.5	4.5
1978	1	1	1	1	1	6.5	4.5	4.5	4.5	4.5
1980	2.5	2	1.5	1.5	1.5	4.5	4.5	4.5	4.5	4.5
1982	1.5	1.5	1	1	1	4.5	4.5	4.5	4.5	4.5
1983	2.5	1.5	1.5	1	1	4.5	4.5	4.5	8	8
1984	2	1.5	1.5	1.5	1.5	4.5	6.5	4.5	4.5	4.5

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BAHAGIAN KEJURUTERAAN PANTAI
JABATAN PENGAIRAN DAN SALIRAN MALAYSIA
WAVE STATISTICS
MAXIMUM WAVE HEIGHT

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 180 [165 - 195 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

YEAR		MAXIMUM WAVE HEIGHT METERS						WAVE PERIOD SECONDS				
		1	2	3	4	5		1	2	3	4	5
1951		0.5	0.5	0.5	0.5	-		6.5	4.5	4.5	4.5	-
1952		0.5	0.5	0.5	0.5	0.5		6.5	6.5	4.5	4.5	4.5
1953		1	0.5	0.5	0.5	0.5		4.5	6.5	6.5	4.5	4.5
1954		1.5	1	1	-	-		6.5	4.5	4.5	-	-
1955		2	0.5	-	-	-		4.5	4.5	-	-	-
1956		1	0.5	0.5	-	-		6.5	4.5	4.5	-	-
1957		0.5	0.5	-	-	-		4.5	4.5	-	-	-
1958		1	0.5	0.5	-	-		6.5	4.5	4.5	-	-
1959		1	-	-	-	-		4.5	-	-	-	-
1960		0.5	-	-	-	-		4.5	-	-	-	-
1961		0.5	-	-	-	-		4.5	-	-	-	-
1962		0.5	0.5	-	-	-		4.5	4.5	-	-	-
1964		1	1	0.5	0.5	0.5		6.5	4.5	4.5	4.5	4.5
1965		1	1	0.5	0.5	0.5		4.5	4.5	4.5	4.5	4.5
1966		1.5	1	1	1	1		4.5	4.5	4.5	4.5	4.5
1967		1	1	1	1	1		8.5	6.5	6.5	4.5	4.5
1969		0.5	0.5	0.5	0.5	0.5		11	4.5	4.5	4.5	4.5
1970		1.5	1	1	1	0.5		4.5	7	4.5	4.5	13
1971		1.5	1	1	1	1		4.5	14	4.5	4.5	4.5
1972		1.5	1.5	1.5	1.5	1		13	8	4.5	4.5	6
1973		2	1.5	1	1	1		8	12	6	4.5	4.5
1974		2	1.5	1	1	1		4.5	10	4.5	4.5	4.5
1975		3	2.5	1.5	1	1		8	6	4.5	4.5	4.5
1976		2	1.5	1	1	0.5		4.5	6	14	4.5	4.5
1978		1.5	1	1	1	1		4.5	4.5	4.5	4.5	4.5
1979		2	1.5	1	1	1		4.5	4.5	14	6	6
1980		1	1	1	0.5	0.5		4.5	4.5	4.5	8	4.5
1982		1.5	1.5	1	1	1		4.5	4.5	4.5	4.5	4.5
1983		1.5	1	1	0.5	0.5		6	4.5	4.5	4.5	4.5
1984		2.5	2	1.5	1	1		6.5	4.5	4.5	4.5	4.5

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BAHAGIAN KEJURUTERAAN PANTAI
JABATAN PENGAIRAN DAN SALIRAN MALAYSIA
WAVE STATISTICS
MAXIMUM WAVE HEIGHT

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 210 [195 - 225 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

YEAR	MAXIMUM WAVE HEIGHT METERS					WAVE PERIOD SECONDS				
	1	2	3	4	5	1	2	3	4	5
1949	1	-	-	-	-	4.5	-	-	-	-
1950	0.5	0.5	0.5	-	-	4.5	4.5	4.5	-	-
1951	1	0.5	0.5	0.5	0.5	4.5	8.5	4.5	4.5	4.5
1952	0.5	0.5	-	-	-	8.5	4.5	-	-	-
1953	1.5	1	1	0.5	0.5	4.5	6.5	6.5	4.5	4.5
1954	1.5	1	1	0.5	0.5	8.5	4.5	4.5	4.5	4.5
1955	1	0.5	0.5	0.5	-	6.5	6.5	4.5	4.5	-
1956	0.5	-	-	-	-	4.5	-	-	-	-
1958	0.5	-	-	-	-	4.5	-	-	-	-
1959	0.5	-	-	-	-	4.5	-	-	-	-
1960	1	0.5	0.5	0.5	0.5	4.5	4.5	4.5	4.5	4.5
1961	1	-	-	-	-	4.5	-	-	-	-
1962	2	1	0.5	-	-	6.5	4.5	4.5	-	-
1963	0.5	0.5	-	-	-	4.5	4.5	-	-	-
1964	2	1	0.5	-	-	6.5	6.5	4.5	-	-
1965	1.5	1	1	1	0.5	6.5	6.5	4.5	4.5	4.5
1966	1	0.5	0.5	0.5	0.5	4.5	4.5	4.5	4.5	4.5
1967	1.5	1	0.5	0.5	0.5	8.5	4.5	4.5	4.5	4.5
1968	1.5	-	-	-	-	4.5	-	-	-	-
1969	2	1	0.5	0.5	0.5	9	4.5	8	4.5	4.5
1970	1.5	1	0.5	0.5	0.5	4.5	4.5	4.5	4.5	4.5
1971	1.5	1	0.5	0.5	0.5	4.5	4.5	4.5	4.5	4.5
1972	2	1.5	0.5	0.5	0.5	4.5	12	14	4.5	4.5
1973	2	0.5	0.5	0.5	0.5	4.5	4.5	4.5	4.5	4.5
1974	1	0.5	0.5	0.5	0.5	4.5	4.5	4.5	4.5	4.5
1975	2.5	1.5	1	0.5	0.5	4.5	4.5	13	4.5	4.5
1976	2	1	1	0.5	0.5	4.5	13	4.5	10.5	4.5
1977	2	1.5	1	1	1	4.5	4.5	14	13	6
1978	1	1	1	1	0.5	9	6	6	4.5	7
1979	3	2	2	1.5	1	8	4.5	4.5	13	13
1981	1	1	1	1	0.5	13	4.5	4.5	4.5	14
1982	1	1	0.5	0.5	0.5	6	4.5	4.5	4.5	4.5
1983	1.5	1.5	1	1	0.5	4.5	4.5	4.5	4.5	4.5
1984	1.5	1	1	1	1	4.5	6	4.5	4.5	4.5

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BAHAGIAN KEJURUTERAAN PANTAI
JABATAN PENGAIRAN DAN SALIRAN MALAYSIA
WAVE STATISTICS
MAXIMUM WAVE HEIGHT

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 240 [225 - 255 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

YEAR		MAXIMUM WAVE HEIGHT METERS						WAVE PERIOD SECONDS				
		1	2	3	4	5		1	2	3	4	5
1949		0.5	-	-	-	-		4.5	-	-	-	-
1951		1	0.5	0.5	-	-		4.5	4.5	4.5	-	-
1952		2	1	1	0.5	0.5		10.5	4.5	4.5	4.5	4.5
1953		1.5	1	0.5	0.5	-		6.5	4.5	4.5	4.5	-
1954		1	0.5	0.5	-	-		4.5	4.5	4.5	-	-
1955		1	0.5	0.5	0.5	-		6.5	4.5	4.5	4.5	-
1956		1.5	0.5	-	-	-		8.5	4.5	-	-	-
1957		1	1	-	-	-		4.5	4.5	-	-	-
1958		1	1	0.5	-	-		4.5	4.5	4.5	-	-
1960		1	1	0.5	-	-		4.5	4.5	4.5	-	-
1961		1	0.5	-	-	-		4.5	4.5	-	-	-
1962		0.5	-	-	-	-		6.5	-	-	-	-
1963		1	0.5	-	-	-		4.5	4.5	-	-	-
1964		0.5	0.5	0.5	0.5	0.5		6.5	4.5	4.5	4.5	4.5
1965		1	0.5	-	-	-		4.5	4.5	-	-	-
1966		1	1	0.5	-	-		4.5	4.5	4.5	-	-
1969		0.5	0.5	0.5	-	-		4.5	4.5	4.5	-	-
1970		1.5	1	1	1	0.5		4.5	4.5	4.5	4.5	4.5
1971		2	1	1	1	1		4.5	4.5	4.5	4.5	4.5
1972		1.5	1	0.5	0.5	0.5		4.5	4.5	4.5	4.5	4.5
1973		2	1	0.5	0.5	0.5		7	7	4.5	4.5	4.5
1974		2.5	2	1	1	0.5		8.5	7	6.5	4.5	4.5
1975		3.5	1.5	1.5	1	1		7	10.5	4.5	7	4.5
1976		1	1	0.5	0.5	0.5		4.5	4.5	9	9	6.5
1977		2.5	1	1	1	1		10	4.5	4.5	4.5	4.5
1978		3	2	2	2	1		6	7	7	6	6
1979		1.5	1	0.5	0.5	0.5		4.5	4.5	6	6	4.5
1980		2.5	1	1	1	1		6.5	6	6	4.5	4.5
1981		1.5	1	1	1	1		6	8	4.5	4.5	4.5
1982		1	0.5	0.5	0.5	0.5		4.5	4.5	4.5	4.5	4.5
1984		1.5	1.5	1.5	1	1		4.5	4.5	4.5	4.5	4.5

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JABATAN PENGAIRAN DAN SALIRAN MALAYSIA
WAVE STATISTICS
MAXIMUM WAVE HEIGHT

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 270 [255 - 285 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

YEAR		MAXIMUM WAVE HEIGHT METERS						WAVE PERIOD SECONDS				
		1	2	3	4	5		1	2	3	4	5
1949		1	0.5	0.5	-	-		4.5	4.5	4.5	-	-
1950		1.5	1	1	1	1		10.5	4.5	4.5	4.5	4.5
1951		1	1	0.5	0.5	0.5		4.5	4.5	6.5	4.5	4.5
1952		1	1	1	0.5	0.5		4.5	4.5	4.5	6.5	6.5
1953		1.5	1	1	1	1		8.5	6.5	4.5	4.5	4.5
1954		1.5	1	0.5	0.5	-		4.5	4.5	4.5	4.5	-
1955		1	0.5	-	-	-		4.5	4.5	-	-	-
1956		1	1	0.5	-	-		8.5	4.5	4.5	-	-
1957		1	1	1	1	-		8.5	4.5	4.5	4.5	-
1958		0.5	0.5	0.5	0.5	-		4.5	4.5	4.5	4.5	-
1959		1.5	1	-	-	-		4.5	4.5	-	-	-
1960		1	1	1	0.5	0.5		6.5	4.5	4.5	4.5	4.5
1961		1.5	0.5	-	-	-		6.5	4.5	-	-	-
1963		0.5	-	-	-	-		4.5	-	-	-	-
1964		1.5	1	1	1	1		4.5	8.5	6.5	6.5	4.5
1965		1.5	1.5	1	1	0.5		6.5	6.5	4.5	4.5	4.5
1966		2.5	2	2	2	1.5		8.5	8.5	8.5	4.5	4.5
1967		2	1.5	1.5	1.5	1		4.5	6.5	6.5	4.5	6.5
1968		0.5	-	-	-	-		4.5	-	-	-	-
1969		1	1	1	0.5	0.5		6	6	4.5	11	4.5
1970		1	1	1	0.5	0.5		6	4.5	4.5	14	4.5
1971		1	1	1	1	1		14	13	13	7	7
1972		1	1	1	0.5	0.5		4.5	4.5	4.5	4.5	4.5
1973		2	2	1.5	1	1		7	4.5	4.5	6	4.5
1974		1	1	1	1	1		10.5	4.5	4.5	4.5	4.5
1975		2	1.5	1	1	1		4.5	4.5	6	4.5	4.5
1976		2	1.5	1.5	1.5	1.5		4.5	4.5	4.5	4.5	4.5
1977		3.5	1.5	1.5	1.5	1		4.5	7	6	4.5	4.5
1978		2	1.5	1.5	1	1		8	4.5	4.5	13	7
1979		2	1.5	1.5	1.5	1		6	8	6	4.5	6
1981		2.5	2	2	1	1		6	14	7	14	7
1982		1	1	1	1	1		8	6	4.5	4.5	4.5
1983		2.5	1	1	1	0.5		4.5	4.5	4.5	4.5	4.5
1984		1.5	1.5	1	1	1		6	4.5	6	4.5	4.5

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JABATAN PENGAIRAN DAN SALIRAN MALAYSIA
WAVE STATISTICS
MAXIMUM WAVE HEIGHT

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 300 [285 - 315 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

YEAR		MAXIMUM WAVE HEIGHT METERS						WAVE PERIOD SECONDS				
		1	2	3	4	5		1	2	3	4	5
1949		1	0.5	0.5	0.5	0.5		4.5	4.5	4.5	4.5	4.5
1950		1	1	1	1	0.5		4.5	4.5	4.5	4.5	6.5
1951		1	1	1	1	0.5		8.5	4.5	4.5	4.5	4.5
1952		2	1.5	1.5	1	1		6.5	4.5	4.5	4.5	4.5
1953		1.5	1	1	1	0.5		4.5	4.5	4.5	4.5	4.5
1954		2	1.5	1.5	1.5	1		4.5	8.5	6.5	4.5	6.5
1955		1.5	1.5	1.5	1	1		6.5	6.5	4.5	4.5	4.5
1956		1	0.5	0.5	0.5	0.5		4.5	4.5	4.5	4.5	4.5
1957		0.5	0.5	0.5	-	-		4.5	4.5	4.5	-	-
1958		1.5	0.5	0.5	0.5	0.5		6.5	4.5	4.5	4.5	4.5
1959		0.5	-	-	-	-		4.5	-	-	-	-
1960		1	0.5	0.5	-	-		6.5	4.5	4.5	-	-
1961		2	1	1	0.5	0.5		4.5	4.5	4.5	4.5	4.5
1963		0.5	-	-	-	-		4.5	-	-	-	-
1964		2	2	2	1.5	1.5		12.5	12.5	4.5	12.5	4.5
1965		1	1	1	1	1		6.5	6.5	6.5	6.5	4.5
1966		2	1.5	1.5	1.5	1.5		6.5	6.5	6.5	6.5	6.5
1967		2	1.5	1	1	1		4.5	4.5	6.5	4.5	4.5
1968		0.5	-	-	-	-		7	-	-	-	-
1969		1.5	1.5	1	1	1		4.5	4.5	4.5	4.5	4.5
1970		2.5	1.5	1.5	1.5	1.5		4.5	7	7	4.5	4.5
1971		2.5	2.5	1.5	1.5	1		7	7	8	4.5	20.5
1972		2	1.5	1.5	1.5	1		6	9	6	4.5	6.5
1973		3.5	3.5	2	2	1.5		7	4.5	4.5	4.5	4.5
1975		4.5	2	1.5	1.5	1.5		13	4.5	4.5	4.5	4.5
1976		2.5	2	1.5	1.5	1.5		10	6	14	7	7
1977		2.5	1.5	1.5	1.5	1.5		4.5	8	6	6	4.5
1978		3.5	2.5	2	2	2		4.5	4.5	6	4.5	4.5
1979		2	2	2	2	2		7	6	6	6	6
1982		2	2	1.5	1.5	1.5		6.5	6	8	4.5	4.5
1983		2	2	1.5	1.5	1		6.5	4.5	4.5	4.5	22.5
1984		2.5	1.5	1.5	1.5	1.5		4.5	7	4.5	4.5	4.5

Reference : Mars2627.dbf
Processed by : zanal Abidin Hj. Ismail
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BAHAGIAN KEJURUTERAAN PANTAI
JABATAN PENGAIRAN DAN SALIRAN MALAYSIA
WAVE STATISTICS
MAXIMUM WAVE HEIGHT

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 330 [315 - 345 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

YEAR		MAXIMUM WAVE HEIGHT METERS						WAVE PERIOD SECONDS				
		1	2	3	4	5		1	2	3	4	5
1949		1	1	1	0.5	0.5		10.5	8.5	6.5	6.5	4.5
1950		2	1	0.5	0.5	0.5		4.5	8.5	6.5	4.5	4.5
1951		0.5	0.5	0.5	-	-		6.5	4.5	4.5	-	-
1952		1	1	1	1	0.5		6.5	4.5	4.5	4.5	4.5
1953		1	1	1	1	1		8.5	4.5	4.5	4.5	4.5
1954		1.5	1	1	1	1		4.5	10.5	4.5	4.5	4.5
1955		1.5	1	1	1	0.5		6.5	6.5	4.5	4.5	4.5
1956		1.5	0.5	0.5	0.5	-		6.5	4.5	4.5	4.5	-
1957		1	0.5	0.5	0.5	-		4.5	4.5	4.5	4.5	-
1958		1	0.5	0.5	0.5	0.5		6.5	6.5	6.5	4.5	4.5
1959		1	1	0.5	-	-		4.5	4.5	4.5	-	-
1960		1	0.5	0.5	0.5	0.5		4.5	4.5	4.5	4.5	4.5
1961		1	1	1	0.5	0.5		4.5	4.5	4.5	6.5	4.5
1962		1	1	1	0.5	0.5		8.5	4.5	4.5	4.5	4.5
1963		1.5	0.5	0.5	0.5	0.5		6.5	6.5	4.5	4.5	4.5
1964		1.5	1.5	1	1	1		6.5	4.5	6.5	6.5	4.5
1965		2.5	1	1	1	1		6.5	6.5	6.5	6.5	4.5
1966		1.5	1.5	1.5	1	1		4.5	4.5	4.5	6.5	6.5
1967		2	1.5	1.5	1	1		4.5	4.5	4.5	4.5	4.5
1968		1.5	0.5	-	-	-		4.5	4.5	-	-	-
1969		1.5	1	1	1	1		4.5	7	6	4.5	4.5
1970		2	1.5	1.5	1.5	1		6	8	6	4.5	14
1971		2.5	2.5	2.5	2	1.5		6	6	4.5	6.5	8
1972		1.5	1.5	1	1	1		4.5	4.5	14	4.5	4.5
1973		4	2.5	1.5	1.5	1.5		4.5	10	7	4.5	4.5
1974		2	1.5	1.5	1.5	1.5		11	14	6.5	4.5	4.5
1976		1.5	1.5	1.5	1.5	1.5		14	8.5	7	7	6
1977		1.5	1.5	1.5	1.5	1		4.5	4.5	4.5	4.5	7
1978		2	1.5	1.5	1.5	1		6	4.5	4.5	4.5	14
1979		2.5	2	2	1.5	1.5		4.5	4.5	4.5	7	6.5
1980		2	2	1.5	1.5	1.5		6	6	8	8	4.5
1982		3	2	1.5	1.5	1		6	8	4.5	4.5	4.5
1983		2.5	2	1.5	1.5	1.5		7	12	8.5	6	4.5
1984		5	2.5	2	1.5	1.5		4.5	9	4.5	8	6

Reference : Mars2627.dbf
Processed by : zanal Abidin Hj. Ismail
Date Processed : 07-03-2006
Fax Number : 03-26936625
Tel Number : 03-26972043
e-mail Address : zanal@water.gov.my

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 150 [135 - 165 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Calculation:
Rearrange Ho in receding manner:

No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2
1	2.5	6.25	38	1.5	2.25	75	1	1	112	0.5	0.25
2	2.5	6.25	39	1.5	2.25	76	1	1	113	0.5	0.25
3	2	4	40	1.5	2.25	77	1	1	114	0.5	0.25
4	2	4	41	1.5	2.25	78	1	1	115	0.5	0.25
5	2	4	42	1.5	2.25	79	1	1	116	0.5	0.25
6	2	4	43	1.5	2.25	80	1	1	117	0.5	0.25
7	2	4	44	1	1	81	1	1	118	0.5	0.25
8	2	4	45	1	1	82	1	1	119	0.5	0.25
9	2	4	46	1	1	83	1	1	120	0.5	0.25
10	2	4	47	1	1	84	1	1	121	0.5	0.25
11	2	4	48	1	1	85	1	1	122	0.5	0.25
12	1.5	2.25	49	1	1	86	1	1	123	0.5	0.25
13	1.5	2.25	50	1	1	87	1	1	124	0.5	0.25
14	1.5	2.25	51	1	1	88	1	1	125	0.5	0.25
15	1.5	2.25	52	1	1	89	1	1	126	0.5	0.25
16	1.5	2.25	53	1	1	90	1	1	127	0.5	0.25
17	1.5	2.25	54	1	1	91	1	1	128	0.5	0.25
18	1.5	2.25	55	1	1	92	1	1	129	0.5	0.25
19	1.5	2.25	56	1	1	93	1	1	130	0.5	0.25
20	1.5	2.25	57	1	1	94	1	1	131	0.5	0.25
21	1.5	2.25	58	1	1	95	1	1	132	0.5	0.25
22	1.5	2.25	59	1	1	96	1	1	133	0.5	0.25
23	1.5	2.25	60	1	1	97	1	1	134	0.5	0.25
24	1.5	2.25	61	1	1	98	1	1	135	0.5	0.25
25	1.5	2.25	62	1	1	99	1	1	136	0.5	0.25
26	1.5	2.25	63	1	1	100	1	1	137	0.5	0.25
27	1.5	2.25	64	1	1	101	1	1	138	0.5	0.25
28	1.5	2.25	65	1	1	102	1	1	139	0.5	0.25
29	1.5	2.25	66	1	1	103	1	1	140	0.5	0.25
30	1.5	2.25	67	1	1	104	0.5	0.25	141	0.5	0.25
31	1.5	2.25	68	1	1	105	0.5	0.25	142	0.5	0.25
32	1.5	2.25	69	1	1	106	0.5	0.25	143	0.5	0.25
33	1.5	2.25	70	1	1	107	0.5	0.25	144	0.5	0.25
34	1.5	2.25	71	1	1	108	0.5	0.25	145	0.5	0.25
35	1.5	2.25	72	1	1	109	0.5	0.25	Total		191
36	1.5	2.25	73	1	1	110	0.5	0.25			
37	1.5	2.25	74	1	1	111	0.5	0.25			

Hs = Average wave height of the highest 1/3 of the waves

$$Hs = \overline{H_{1/3}}$$

$$Hs = \frac{\sum_{i=48}^{n} Hi}{N}$$

$$Hs = \frac{76}{48}$$

$$Hs = 1.5833m$$

$$Hrms = \sqrt{\sum \frac{Hi^2}{N}}$$

$$Hrms = \sqrt{\frac{191}{145}}$$

$$Hrms = 1.1477m$$

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 150 [135 - 165 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Calculation:
Rearrange To in receding manner:

No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2
1	16.5	272.25	38	4.5	20.25	75	4.5	20.25	112	4.5	20.25
2	14	196	39	4.5	20.25	76	4.5	20.25	113	4.5	20.25
3	13	169	40	4.5	20.25	77	4.5	20.25	114	4.5	20.25
4	12.5	156.25	41	4.5	20.25	78	4.5	20.25	115	4.5	20.25
5	12	144	42	4.5	20.25	79	4.5	20.25	116	4.5	20.25
6	10.5	110.25	43	4.5	20.25	80	4.5	20.25	117	4.5	20.25
7	10	100	44	4.5	20.25	81	4.5	20.25	118	4.5	20.25
8	9	81	45	4.5	20.25	82	4.5	20.25	119	4.5	20.25
9	8.5	72.25	46	4.5	20.25	83	4.5	20.25	120	4.5	20.25
10	8.5	72.25	47	4.5	20.25	84	4.5	20.25	121	4.5	20.25
11	8.5	72.25	48	4.5	20.25	85	4.5	20.25	122	4.5	20.25
12	8.5	72.25	49	4.5	20.25	86	4.5	20.25	123	4.5	20.25
13	8	64	50	4.5	20.25	87	4.5	20.25	124	4.5	20.25
14	8	64	51	4.5	20.25	88	4.5	20.25	125	4.5	20.25
15	8	64	52	4.5	20.25	89	4.5	20.25	126	4.5	20.25
16	8	64	53	4.5	20.25	90	4.5	20.25	127	4.5	20.25
17	7	49	54	4.5	20.25	91	4.5	20.25	128	4.5	20.25
18	6.5	42.25	55	4.5	20.25	92	4.5	20.25	129	4.5	20.25
19	6.5	42.25	56	4.5	20.25	93	4.5	20.25	130	4.5	20.25
20	6.5	42.25	57	4.5	20.25	94	4.5	20.25	131	4.5	20.25
21	6.5	42.25	58	4.5	20.25	95	4.5	20.25	132	4.5	20.25
22	6.5	42.25	59	4.5	20.25	96	4.5	20.25	133	4.5	20.25
23	6.5	42.25	60	4.5	20.25	97	4.5	20.25	134	4.5	20.25
24	6.5	42.25	61	4.5	20.25	98	4.5	20.25	135	4.5	20.25
25	6.5	42.25	62	4.5	20.25	99	4.5	20.25	136	4.5	20.25
26	6.5	42.25	63	4.5	20.25	100	4.5	20.25	137	4.5	20.25
27	6.5	42.25	64	4.5	20.25	101	4.5	20.25	138	4.5	20.25
28	6.5	42.25	65	4.5	20.25	102	4.5	20.25	139	4.5	20.25
29	6.5	42.25	66	4.5	20.25	103	4.5	20.25	140	4.5	20.25
30	6.5	42.25	67	4.5	20.25	104	4.5	20.25	141	4.5	20.25
31	6.5	42.25	68	4.5	20.25	105	4.5	20.25	142	4.5	20.25
32	6.5	42.25	69	4.5	20.25	106	4.5	20.25	143	4.5	20.25
33	6.5	42.25	70	4.5	20.25	107	4.5	20.25	144	4.5	20.25
34	6.5	42.25	71	4.5	20.25	108	4.5	20.25	145	4.5	20.25
35	6	36	72	4.5	20.25	109	4.5	20.25	Total		4820.25
36	6	36	73	4.5	20.25	110	4.5	20.25			
37	4.5	20.25	74	4.5	20.25	111	4.5	20.25			

Ts = Average wave period of the highest 1/3 of the waves

$$Ts = \overline{T_{1/3}}$$

$$Ts = \frac{\sum_{i=48}^{n} Ti}{N}$$

$$Ts = \frac{347}{48}$$

$$Ts = 7.2292s$$

$$Trms = \sqrt{\sum \frac{Ti^2}{N}}$$

$$Trms = \sqrt{\frac{4820.25}{145}}$$

$$Trms = 5.7657s$$

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 180 [165 - 195 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Calculation:
Rearrange Ho in receding manner:

No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2
1	3	9	39	1	1	77	1	1	115	0.5	0.25
2	2.5	6.25	40	1	1	78	1	1	116	0.5	0.25
3	2.5	6.25	41	1	1	79	1	1	117	0.5	0.25
4	2	4	42	1	1	80	1	1	118	0.5	0.25
5	2	4	43	1	1	81	1	1	119	0.5	0.25
6	2	4	44	1	1	82	0.5	0.25	120	0.5	0.25
7	2	4	45	1	1	83	0.5	0.25	121	0.5	0.25
8	2	4	46	1	1	84	0.5	0.25	122	0.5	0.25
9	2	4	47	1	1	85	0.5	0.25	Total		150.25
10	1.5	2.25	48	1	1	86	0.5	0.25			
11	1.5	2.25	49	1	1	87	0.5	0.25			
12	1.5	2.25	50	1	1	88	0.5	0.25			
13	1.5	2.25	51	1	1	89	0.5	0.25			
14	1.5	2.25	52	1	1	90	0.5	0.25			
15	1.5	2.25	53	1	1	91	0.5	0.25			
16	1.5	2.25	54	1	1	92	0.5	0.25			
17	1.5	2.25	55	1	1	93	0.5	0.25			
18	1.5	2.25	56	1	1	94	0.5	0.25			
19	1.5	2.25	57	1	1	95	0.5	0.25			
20	1.5	2.25	58	1	1	96	0.5	0.25			
21	1.5	2.25	59	1	1	97	0.5	0.25			
22	1.5	2.25	60	1	1	98	0.5	0.25			
23	1.5	2.25	61	1	1	99	0.5	0.25			
24	1.5	2.25	62	1	1	100	0.5	0.25			
25	1.5	2.25	63	1	1	101	0.5	0.25			
26	1.5	2.25	64	1	1	102	0.5	0.25			
27	1.5	2.25	65	1	1	103	0.5	0.25			
28	1	1	66	1	1	104	0.5	0.25			
29	1	1	67	1	1	105	0.5	0.25			
30	1	1	68	1	1	106	0.5	0.25			
31	1	1	69	1	1	107	0.5	0.25			
32	1	1	70	1	1	108	0.5	0.25			
33	1	1	71	1	1	109	0.5	0.25			
34	1	1	72	1	1	110	0.5	0.25			
35	1	1	73	1	1	111	0.5	0.25			
36	1	1	74	1	1	112	0.5	0.25			
37	1	1	75	1	1	113	0.5	0.25			
38	1	1	76	1	1	114	0.5	0.25			

Hs = Average wave height of the highest 1/3 of the waves

$$Hs = \overline{H_{1/3}}$$

$$Hs = \frac{\sum_{i=41}^{n} Hi}{N}$$

$$Hs = \frac{61}{41}$$

$$Hs = 1.4878m$$

$$Hrms = \sqrt{\sum \frac{Hi^2}{N}}$$

$$Hrms = \sqrt{\frac{150.25}{122}}$$

$$Hrms = 1.1098m$$

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 180 [165 - 195 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Calculation:
Rearrange To in receding manner:

No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2
1	14	196	40	4.5	20.25	79	4.5	20.25	118	4.5	20.25
2	14	196	41	4.5	20.25	80	4.5	20.25	119	4.5	20.25
3	14	196	42	4.5	20.25	81	4.5	20.25	120	4.5	20.25
4	13	169	43	4.5	20.25	82	4.5	20.25	121	4.5	20.25
5	13	169	44	4.5	20.25	83	4.5	20.25	122	4.5	20.25
6	12	144	45	4.5	20.25	84	4.5	20.25	Total		3885.25
7	11	121	46	4.5	20.25	85	4.5	20.25			
8	10	100	47	4.5	20.25	86	4.5	20.25			
9	8.5	72.25	48	4.5	20.25	87	4.5	20.25			
10	8	64	49	4.5	20.25	88	4.5	20.25			
11	8	64	50	4.5	20.25	89	4.5	20.25			
12	8	64	51	4.5	20.25	90	4.5	20.25			
13	8	64	52	4.5	20.25	91	4.5	20.25			
14	7	49	53	4.5	20.25	92	4.5	20.25			
15	6.5	42.25	54	4.5	20.25	93	4.5	20.25			
16	6.5	42.25	55	4.5	20.25	94	4.5	20.25			
17	6.5	42.25	56	4.5	20.25	95	4.5	20.25			
18	6.5	42.25	57	4.5	20.25	96	4.5	20.25			
19	6.5	42.25	58	4.5	20.25	97	4.5	20.25			
20	6.5	42.25	59	4.5	20.25	98	4.5	20.25			
21	6.5	42.25	60	4.5	20.25	99	4.5	20.25			
22	6.5	42.25	61	4.5	20.25	100	4.5	20.25			
23	6.5	42.25	62	4.5	20.25	101	4.5	20.25			
24	6.5	42.25	63	4.5	20.25	102	4.5	20.25			
25	6.5	42.25	64	4.5	20.25	103	4.5	20.25			
26	6.5	42.25	65	4.5	20.25	104	4.5	20.25			
27	6	36	66	4.5	20.25	105	4.5	20.25			
28	6	36	67	4.5	20.25	106	4.5	20.25			
29	6	36	68	4.5	20.25	107	4.5	20.25			
30	6	36	69	4.5	20.25	108	4.5	20.25			
31	6	36	70	4.5	20.25	109	4.5	20.25			
32	6	36	71	4.5	20.25	110	4.5	20.25			
33	6	36	72	4.5	20.25	111	4.5	20.25			
34	4.5	20.25	73	4.5	20.25	112	4.5	20.25			
35	4.5	20.25	74	4.5	20.25	113	4.5	20.25			
36	4.5	20.25	75	4.5	20.25	114	4.5	20.25			
37	4.5	20.25	76	4.5	20.25	115	4.5	20.25			
38	4.5	20.25	77	4.5	20.25	116	4.5	20.25			
39	4.5	20.25	78	4.5	20.25	117	4.5	20.25			

Ts = Average wave period of the highest 1/3 of the waves

$$Ts = \overline{T_{1/3}}$$

$$Ts = \frac{\sum_{i=41}^{n} Ti}{N}$$

$$Ts = \frac{304.5}{41}$$

$$Ts = 7.4268s$$

$$Trms = \sqrt{\sum \frac{Ti^2}{N}}$$

$$Trms = \sqrt{\frac{4229.5}{122}}$$

$$Trms = 5.8880s$$

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 210 [195 - 225 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Calculation:
Rearrange Ho in receding manner:

No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2
1	3	9	39	1	1	77	0.5	0.25	115	0.5	0.25
2	2.5	6.25	40	1	1	78	0.5	0.25	116	0.5	0.25
3	2	4	41	1	1	79	0.5	0.25	117	0.5	0.25
4	2	4	42	1	1	80	0.5	0.25	118	0.5	0.25
5	2	4	43	1	1	81	0.5	0.25	119	0.5	0.25
6	2	4	44	1	1	82	0.5	0.25	120	0.5	0.25
7	2	4	45	1	1	83	0.5	0.25	121	0.5	0.25
8	2	4	46	1	1	84	0.5	0.25	122	0.5	0.25
9	2	4	47	1	1	85	0.5	0.25	123	0.5	0.25
10	2	4	48	1	1	86	0.5	0.25	124	0.5	0.25
11	2	4	49	1	1	87	0.5	0.25	125	0.5	0.25
12	1.5	2.25	50	1	1	88	0.5	0.25	126	0.5	0.25
13	1.5	2.25	51	1	1	89	0.5	0.25	127	0.5	0.25
14	1.5	2.25	52	1	1	90	0.5	0.25	128	0.5	0.25
15	1.5	2.25	53	1	1	91	0.5	0.25	129	0.5	0.25
16	1.5	2.25	54	1	1	92	0.5	0.25	130	0.5	0.25
17	1.5	2.25	55	1	1	93	0.5	0.25	131	0.5	0.25
18	1.5	2.25	56	1	1	94	0.5	0.25	132	0.5	0.25
19	1.5	2.25	57	1	1	95	0.5	0.25	133	0.5	0.25
20	1.5	2.25	58	1	1	96	0.5	0.25	Total		142
21	1.5	2.25	59	1	1	97	0.5	0.25			
22	1.5	2.25	60	1	1	98	0.5	0.25			
23	1.5	2.25	61	1	1	99	0.5	0.25			
24	1.5	2.25	62	1	1	100	0.5	0.25			
25	1.5	2.25	63	1	1	101	0.5	0.25			
26	1	1	64	1	1	102	0.5	0.25			
27	1	1	65	1	1	103	0.5	0.25			
28	1	1	66	1	1	104	0.5	0.25			
29	1	1	67	1	1	105	0.5	0.25			
30	1	1	68	1	1	106	0.5	0.25			
31	1	1	69	0.5	0.25	107	0.5	0.25			
32	1	1	70	0.5	0.25	108	0.5	0.25			
33	1	1	71	0.5	0.25	109	0.5	0.25			
34	1	1	72	0.5	0.25	110	0.5	0.25			
35	1	1	73	0.5	0.25	111	0.5	0.25			
36	1	1	74	0.5	0.25	112	0.5	0.25			
37	1	1	75	0.5	0.25	113	0.5	0.25			
38	1	1	76	0.5	0.25	114	0.5	0.25			

Hs = Average wave height of the highest 1/3 of the waves

$$Hs = \overline{H_{1/3}}$$

$$Hs = \frac{\sum_{i=44}^{n} Hi}{N}$$

$$Hs = \frac{63.5}{44}$$

$$Hs = 1.4432m$$

$$Hrms = \sqrt{\sum \frac{Hi^2}{N}}$$

$$Hrms = \sqrt{\frac{142}{133}}$$

$$Hrms = 1.0333m$$

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 210 [195 - 225 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Calculation:
Rearrange To in receding manner:

No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2
1	14	196	39	4.5	20.25	77	4.5	20.25	115	4.5	20.25
2	14	196	40	4.5	20.25	78	4.5	20.25	116	4.5	20.25
3	14	196	41	4.5	20.25	79	4.5	20.25	117	4.5	20.25
4	13	169	42	4.5	20.25	80	4.5	20.25	118	4.5	20.25
5	13	169	43	4.5	20.25	81	4.5	20.25	119	4.5	20.25
6	13	169	44	4.5	20.25	82	4.5	20.25	120	4.5	20.25
7	13	169	45	4.5	20.25	83	4.5	20.25	121	4.5	20.25
8	13	169	46	4.5	20.25	84	4.5	20.25	122	4.5	20.25
9	13	169	47	4.5	20.25	85	4.5	20.25	123	4.5	20.25
10	12	144	48	4.5	20.25	86	4.5	20.25	124	4.5	20.25
11	10.5	110.25	49	4.5	20.25	87	4.5	20.25	125	4.5	20.25
12	9	81	50	4.5	20.25	88	4.5	20.25	126	4.5	20.25
13	9	81	51	4.5	20.25	89	4.5	20.25	127	4.5	20.25
14	8.5	72.25	52	4.5	20.25	90	4.5	20.25	128	4.5	20.25
15	8.5	72.25	53	4.5	20.25	91	4.5	20.25	129	4.5	20.25
16	8.5	72.25	54	4.5	20.25	92	4.5	20.25	130	4.5	20.25
17	8.5	72.25	55	4.5	20.25	93	4.5	20.25	131	4.5	20.25
18	8	64	56	4.5	20.25	94	4.5	20.25	132	4.5	20.25
19	8	64	57	4.5	20.25	95	4.5	20.25	133	4.5	20.25
20	7	49	58	4.5	20.25	96	4.5	20.25	Total		5049.25
21	6.5	42.25	59	4.5	20.25	97	4.5	20.25			
22	6.5	42.25	60	4.5	20.25	98	4.5	20.25			
23	6.5	42.25	61	4.5	20.25	99	4.5	20.25			
24	6.5	42.25	62	4.5	20.25	100	4.5	20.25			
25	6.5	42.25	63	4.5	20.25	101	4.5	20.25			
26	6.5	42.25	64	4.5	20.25	102	4.5	20.25			
27	6.5	42.25	65	4.5	20.25	103	4.5	20.25			
28	6.5	42.25	66	4.5	20.25	104	4.5	20.25			
29	6.5	42.25	67	4.5	20.25	105	4.5	20.25			
30	6	36	68	4.5	20.25	106	4.5	20.25			
31	6	36	69	4.5	20.25	107	4.5	20.25			
32	6	36	70	4.5	20.25	108	4.5	20.25			
33	6	36	71	4.5	20.25	109	4.5	20.25			
34	6	36	72	4.5	20.25	110	4.5	20.25			
35	4.5	20.25	73	4.5	20.25	111	4.5	20.25			
36	4.5	20.25	74	4.5	20.25	112	4.5	20.25			
37	4.5	20.25	75	4.5	20.25	113	4.5	20.25			
38	4.5	20.25	76	4.5	20.25	114	4.5	20.25			

Ts = Average wave period of the highest 1/3 of the waves

$$Ts = \overline{T_{1/3}}$$

$$Ts = \frac{\sum_{i=44}^{n} Ti}{N}$$

$$Ts = \frac{351}{44}$$

$$Ts = 7.9773s$$

$$Trms = \sqrt{\sum \frac{Ti^2}{N}}$$

$$Trms = \sqrt{\frac{5049.25}{133}}$$

$$Trms = 6.1615s$$

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 240 [225 - 255 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Calculation:
Rearrange Ho in receding manner:

No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2
1	3.5	12.25	38	1	1	75	0.5	0.25	112	0.5	0.25
2	3	9	39	1	1	76	0.5	0.25	113	0.5	0.25
3	2.5	6.25	40	1	1	77	0.5	0.25	114	0.5	0.25
4	2.5	6.25	41	1	1	78	0.5	0.25	115	0.5	0.25
5	2.5	6.25	42	1	1	79	0.5	0.25	116	0.5	0.25
6	2	4	43	1	1	80	0.5	0.25	117	0.5	0.25
7	2	4	44	1	1	81	0.5	0.25	118	0.5	0.25
8	2	4	45	1	1	82	0.5	0.25	Total		153.25
9	2	4	46	1	1	83	0.5	0.25			
10	2	4	47	1	1	84	0.5	0.25			
11	2	4	48	1	1	85	0.5	0.25			
12	2	4	49	1	1	86	0.5	0.25			
13	1.5	2.25	50	1	1	87	0.5	0.25			
14	1.5	2.25	51	1	1	88	0.5	0.25			
15	1.5	2.25	52	1	1	89	0.5	0.25			
16	1.5	2.25	53	1	1	90	0.5	0.25			
17	1.5	2.25	54	1	1	91	0.5	0.25			
18	1.5	2.25	55	1	1	92	0.5	0.25			
19	1.5	2.25	56	1	1	93	0.5	0.25			
20	1.5	2.25	57	1	1	94	0.5	0.25			
21	1.5	2.25	58	1	1	95	0.5	0.25			
22	1.5	2.25	59	1	1	96	0.5	0.25			
23	1.5	2.25	60	1	1	97	0.5	0.25			
24	1	1	61	1	1	98	0.5	0.25			
25	1	1	62	1	1	99	0.5	0.25			
26	1	1	63	1	1	100	0.5	0.25			
27	1	1	64	1	1	101	0.5	0.25			
28	1	1	65	1	1	102	0.5	0.25			
29	1	1	66	1	1	103	0.5	0.25			
30	1	1	67	1	1	104	0.5	0.25			
31	1	1	68	1	1	105	0.5	0.25			
32	1	1	69	1	1	106	0.5	0.25			
33	1	1	70	1	1	107	0.5	0.25			
34	1	1	71	1	1	108	0.5	0.25			
35	1	1	72	1	1	109	0.5	0.25			
36	1	1	73	0.5	0.25	110	0.5	0.25			
37	1	1	74	0.5	0.25	111	0.5	0.25			

Hs = Average wave height of the highest 1/3 of the waves

$$Hs = \overline{H_{1/3}}$$

$$Hs = \frac{\sum_{i=39}^{n} Hi}{N}$$

$$Hs = \frac{60.5}{39}$$

$$Hs = 1.5513\text{m}$$

$$Hrms = \sqrt{\sum \frac{Hi^2}{N}}$$

$$Hrms = \sqrt{\frac{153.25}{118}}$$

$$Hrms = 1.1396\text{m}$$

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 240 [225 - 255 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Calculation:
Rearrange To in receding manner:

No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2
1	10.5	110.25	38	4.5	20.25	75	4.5	20.25	112	4.5	20.25
2	10.5	110.25	39	4.5	20.25	76	4.5	20.25	113	4.5	20.25
3	10	100	40	4.5	20.25	77	4.5	20.25	114	4.5	20.25
4	9	81	41	4.5	20.25	78	4.5	20.25	115	4.5	20.25
5	9	81	42	4.5	20.25	79	4.5	20.25	116	4.5	20.25
6	8.5	72.25	43	4.5	20.25	80	4.5	20.25	117	4.5	20.25
7	8.5	72.25	44	4.5	20.25	81	4.5	20.25	118	4.5	20.25
8	8	64	45	4.5	20.25	82	4.5	20.25	Total		2893.5
9	7	49	46	4.5	20.25	83	4.5	20.25			
10	7	49	47	4.5	20.25	84	4.5	20.25			
11	7	49	48	4.5	20.25	85	4.5	20.25			
12	7	49	49	4.5	20.25	86	4.5	20.25			
13	7	49	50	4.5	20.25	87	4.5	20.25			
14	7	49	51	4.5	20.25	88	4.5	20.25			
15	7	49	52	4.5	20.25	89	4.5	20.25			
16	6.5	42.25	53	4.5	20.25	90	4.5	20.25			
17	6.5	42.25	54	4.5	20.25	91	4.5	20.25			
18	6.5	42.25	55	4.5	20.25	92	4.5	20.25			
19	6.5	42.25	56	4.5	20.25	93	4.5	20.25			
20	6.5	42.25	57	4.5	20.25	94	4.5	20.25			
21	6.5	42.25	58	4.5	20.25	95	4.5	20.25			
22	6.5	42.25	59	4.5	20.25	96	4.5	20.25			
23	6	36	60	4.5	20.25	97	4.5	20.25			
24	6	36	61	4.5	20.25	98	4.5	20.25			
25	6	36	62	4.5	20.25	99	4.5	20.25			
26	6	36	63	4.5	20.25	100	4.5	20.25			
27	6	36	64	4.5	20.25	101	4.5	20.25			
28	6	36	65	4.5	20.25	102	4.5	20.25			
29	6	36	66	4.5	20.25	103	4.5	20.25			
30	6	36	67	4.5	20.25	104	4.5	20.25			
31	4.5	20.25	68	4.5	20.25	105	4.5	20.25			
32	4.5	20.25	69	4.5	20.25	106	4.5	20.25			
33	4.5	20.25	70	4.5	20.25	107	4.5	20.25			
34	4.5	20.25	71	4.5	20.25	108	4.5	20.25			
35	4.5	20.25	72	4.5	20.25	109	4.5	20.25			
36	4.5	20.25	73	4.5	20.25	110	4.5	20.25			
37	4.5	20.25	74	4.5	20.25	111	4.5	20.25			

Ts = Average wave period of the highest 1/3 of the waves

$$Ts = \overline{T_{1/3}}$$

$$Ts = \frac{\sum_{i=39}^{n} Ti}{N}$$

$$Ts = \frac{257}{39}$$

$$Ts = 6.5897s$$

$$Trms = \sqrt{\sum \frac{Ti^2}{N}}$$

$$Trms = \sqrt{\frac{3399.75}{118}}$$

$$Trms = 5.3676s$$

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 270 [255 - 285 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Calculation:
Rearrange Ho in receding manner:

No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2
1	3.5	12.25	39	1.5	2.25	77	1	1	115	1	1
2	2.5	6.25	40	1.5	2.25	78	1	1	116	1	1
3	2.5	6.25	41	1.5	2.25	79	1	1	117	1	1
4	2.5	6.25	42	1.5	2.25	80	1	1	118	1	1
5	2	4	43	1.5	2.25	81	1	1	119	0.5	0.25
6	2	4	44	1.5	2.25	82	1	1	120	0.5	0.25
7	2	4	45	1	1	83	1	1	121	0.5	0.25
8	2	4	46	1	1	84	1	1	122	0.5	0.25
9	2	4	47	1	1	85	1	1	123	0.5	0.25
10	2	4	48	1	1	86	1	1	124	0.5	0.25
11	2	4	49	1	1	87	1	1	125	0.5	0.25
12	2	4	50	1	1	88	1	1	126	0.5	0.25
13	2	4	51	1	1	89	1	1	127	0.5	0.25
14	2	4	52	1	1	90	1	1	128	0.5	0.25
15	2	4	53	1	1	91	1	1	129	0.5	0.25
16	2	4	54	1	1	92	1	1	130	0.5	0.25
17	1.5	2.25	55	1	1	93	1	1	131	0.5	0.25
18	1.5	2.25	56	1	1	94	1	1	132	0.5	0.25
19	1.5	2.25	57	1	1	95	1	1	133	0.5	0.25
20	1.5	2.25	58	1	1	96	1	1	134	0.5	0.25
21	1.5	2.25	59	1	1	97	1	1	135	0.5	0.25
22	1.5	2.25	60	1	1	98	1	1	136	0.5	0.25
23	1.5	2.25	61	1	1	99	1	1	137	0.5	0.25
24	1.5	2.25	62	1	1	100	1	1	138	0.5	0.25
25	1.5	2.25	63	1	1	101	1	1	139	0.5	0.25
26	1.5	2.25	64	1	1	102	1	1	140	0.5	0.25
27	1.5	2.25	65	1	1	103	1	1	141	0.5	0.25
28	1.5	2.25	66	1	1	104	1	1	142	0.5	0.25
29	1.5	2.25	67	1	1	105	1	1	143	0.5	0.25
30	1.5	2.25	68	1	1	106	1	1	144	0.5	0.25
31	1.5	2.25	69	1	1	107	1	1	145	0.5	0.25
32	1.5	2.25	70	1	1	108	1	1	146	0.5	0.25
33	1.5	2.25	71	1	1	109	1	1	Total		223
34	1.5	2.25	72	1	1	110	1	1			
35	1.5	2.25	73	1	1	111	1	1			
36	1.5	2.25	74	1	1	112	1	1			
37	1.5	2.25	75	1	1	113	1	1			
38	1.5	2.25	76	1	1	114	1	1			

Hs = Average wave height of the highest 1/3 of the waves

$$Hs = \overline{H_{1/3}}$$

$$Hs = \frac{\sum_{i=49}^{n} Hi}{N}$$

$$Hs = \frac{82}{49}$$

$$Hs = 1.6735\text{m}$$

$$Hrms = \sqrt{\sum \frac{Hi^2}{N}}$$

$$Hrms = \sqrt{\frac{223}{146}}$$

$$Hrms = 1.2359\text{m}$$

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 270 [255 - 285 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Calculation:
Rearrange To in receding manner:

No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2
1	14	196	39	6.5	42.25	77	4.5	20.25	115	4.5	20.25
2	14	196	40	6.5	42.25	78	4.5	20.25	116	4.5	20.25
3	14	196	41	6	36	79	4.5	20.25	117	4.5	20.25
4	14	196	42	6	36	80	4.5	20.25	118	4.5	20.25
5	13	169	43	6	36	81	4.5	20.25	119	4.5	20.25
6	13	169	44	6	36	82	4.5	20.25	120	4.5	20.25
7	13	169	45	6	36	83	4.5	20.25	121	4.5	20.25
8	11	121	46	6	36	84	4.5	20.25	122	4.5	20.25
9	10.5	110.25	47	6	36	85	4.5	20.25	123	4.5	20.25
10	10.5	110.25	48	6	36	86	4.5	20.25	124	4.5	20.25
11	8.5	72.25	49	6	36	87	4.5	20.25	125	4.5	20.25
12	8.5	72.25	50	6	36	88	4.5	20.25	126	4.5	20.25
13	8.5	72.25	51	6	36	89	4.5	20.25	127	4.5	20.25
14	8.5	72.25	52	6	36	90	4.5	20.25	128	4.5	20.25
15	8.5	72.25	53	6	36	91	4.5	20.25	129	4.5	20.25
16	8.5	72.25	54	4.5	20.25	92	4.5	20.25	130	4.5	20.25
17	8.5	72.25	55	4.5	20.25	93	4.5	20.25	131	4.5	20.25
18	8	64	56	4.5	20.25	94	4.5	20.25	132	4.5	20.25
19	8	64	57	4.5	20.25	95	4.5	20.25	133	4.5	20.25
20	8	64	58	4.5	20.25	96	4.5	20.25	134	4.5	20.25
21	7	49	59	4.5	20.25	97	4.5	20.25	135	4.5	20.25
22	7	49	60	4.5	20.25	98	4.5	20.25	136	4.5	20.25
23	7	49	61	4.5	20.25	99	4.5	20.25	137	4.5	20.25
24	7	49	62	4.5	20.25	100	4.5	20.25	138	4.5	20.25
25	7	49	63	4.5	20.25	101	4.5	20.25	139	4.5	20.25
26	7	49	64	4.5	20.25	102	4.5	20.25	140	4.5	20.25
27	7	49	65	4.5	20.25	103	4.5	20.25	141	4.5	20.25
28	6.5	42.25	66	4.5	20.25	104	4.5	20.25	142	4.5	20.25
29	6.5	42.25	67	4.5	20.25	105	4.5	20.25	143	4.5	20.25
30	6.5	42.25	68	4.5	20.25	106	4.5	20.25	144	4.5	20.25
31	6.5	42.25	69	4.5	20.25	107	4.5	20.25	145	4.5	20.25
32	6.5	42.25	70	4.5	20.25	108	4.5	20.25	146	4.5	20.25
33	6.5	42.25	71	4.5	20.25	109	4.5	20.25	Total		5573.75
34	6.5	42.25	72	4.5	20.25	110	4.5	20.25			
35	6.5	42.25	73	4.5	20.25	111	4.5	20.25			
36	6.5	42.25	74	4.5	20.25	112	4.5	20.25			
37	6.5	42.25	75	4.5	20.25	113	4.5	20.25			
38	6.5	42.25	76	4.5	20.25	114	4.5	20.25			

Ts = Average wave period of the highest 1/3 of the waves

$$Ts = \overline{T_{1/3}}$$

$$Ts = \frac{\sum_{i=49}^{n} Ti}{N}$$

$$Ts = \frac{398}{49}$$

$$Ts = 8.1224s$$

$$Trms = \sqrt{\sum \frac{Ti^2}{N}}$$

$$Trms = \sqrt{\frac{5573.75}{146}}$$

$$Trms = 6.1787s$$

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 300 [285 - 315 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Calculation:
Rearrange Ho in receding manner:

No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2
1	4.5	20.25	39	1.5	2.25	77	1.5	2.25	115	1	1
2	3.5	12.25	40	1.5	2.25	78	1.5	2.25	116	1	1
3	3.5	12.25	41	1.5	2.25	79	1.5	2.25	117	1	1
4	3.5	12.25	42	1.5	2.25	80	1.5	2.25	118	1	1
5	2.5	6.25	43	1.5	2.25	81	1.5	2.25	119	1	1
6	2.5	6.25	44	1.5	2.25	82	1.5	2.25	120	0.5	0.25
7	2.5	6.25	45	1.5	2.25	83	1.5	2.25	121	0.5	0.25
8	2.5	6.25	46	1.5	2.25	84	1.5	2.25	122	0.5	0.25
9	2.5	6.25	47	1.5	2.25	85	1	1	123	0.5	0.25
10	2.5	6.25	48	1.5	2.25	86	1	1	124	0.5	0.25
11	2.5	6.25	49	1.5	2.25	87	1	1	125	0.5	0.25
12	2	4	50	1.5	2.25	88	1	1	126	0.5	0.25
13	2	4	51	1.5	2.25	89	1	1	127	0.5	0.25
14	2	4	52	1.5	2.25	90	1	1	128	0.5	0.25
15	2	4	53	1.5	2.25	91	1	1	129	0.5	0.25
16	2	4	54	1.5	2.25	92	1	1	130	0.5	0.25
17	2	4	55	1.5	2.25	93	1	1	131	0.5	0.25
18	2	4	56	1.5	2.25	94	1	1	132	0.5	0.25
19	2	4	57	1.5	2.25	95	1	1	133	0.5	0.25
20	2	4	58	1.5	2.25	96	1	1	134	0.5	0.25
21	2	4	59	1.5	2.25	97	1	1	135	0.5	0.25
22	2	4	60	1.5	2.25	98	1	1	136	0.5	0.25
23	2	4	61	1.5	2.25	99	1	1	137	0.5	0.25
24	2	4	62	1.5	2.25	100	1	1	138	0.5	0.25
25	2	4	63	1.5	2.25	101	1	1	139	0.5	0.25
26	2	4	64	1.5	2.25	102	1	1	140	0.5	0.25
27	2	4	65	1.5	2.25	103	1	1	141	0.5	0.25
28	2	4	66	1.5	2.25	104	1	1	142	0.5	0.25
29	2	4	67	1.5	2.25	105	1	1	143	0.5	0.25
30	2	4	68	1.5	2.25	106	1	1	144	0.5	0.25
31	2	4	69	1.5	2.25	107	1	1	Total		350
32	2	4	70	1.5	2.25	108	1	1			
33	2	4	71	1.5	2.25	109	1	1			
34	2	4	72	1.5	2.25	110	1	1			
35	2	4	73	1.5	2.25	111	1	1			
36	2	4	74	1.5	2.25	112	1	1			
37	1.5	2.25	75	1.5	2.25	113	1	1			
38	1.5	2.25	76	1.5	2.25	114	1	1			

Hs = Average wave height of the highest 1/3 of the waves

$$Hs = \overline{H_{1/3}}$$

$$Hs = \frac{\sum_{i=48}^{n} Hi}{N}$$

$$Hs = \frac{100.5}{48}$$

$$Hs = 2.0938\text{m}$$

$$Hrms = \sqrt{\sum \frac{Hi^2}{N}}$$

$$Hrms = \sqrt{\frac{350}{144}}$$

$$Hrms = 1.559\text{m}$$

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 300 [285 - 315 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Calculation:
Rearrange To in receding manner:

No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2
1	22.5	506.25	39	6.5	42.25	77	4.5	20.25	115	4.5	20.25
2	20.5	420.25	40	6.5	42.25	78	4.5	20.25	116	4.5	20.25
3	14	196	41	6.5	42.25	79	4.5	20.25	117	4.5	20.25
4	13	169	42	6.5	42.25	80	4.5	20.25	118	4.5	20.25
5	12.5	156.25	43	6.5	42.25	81	4.5	20.25	119	4.5	20.25
6	12.5	156.25	44	6.5	42.25	82	4.5	20.25	120	4.5	20.25
7	12.5	156.25	45	6.5	42.25	83	4.5	20.25	121	4.5	20.25
8	10	100	46	6	36	84	4.5	20.25	122	4.5	20.25
9	9	81	47	6	36	85	4.5	20.25	123	4.5	20.25
10	8.5	72.25	48	6	36	86	4.5	20.25	124	4.5	20.25
11	8.5	72.25	49	6	36	87	4.5	20.25	125	4.5	20.25
12	8	64	50	6	36	88	4.5	20.25	126	4.5	20.25
13	8	64	51	6	36	89	4.5	20.25	127	4.5	20.25
14	8	64	52	6	36	90	4.5	20.25	128	4.5	20.25
15	7	49	53	6	36	91	4.5	20.25	129	4.5	20.25
16	7	49	54	6	36	92	4.5	20.25	130	4.5	20.25
17	7	49	55	6	36	93	4.5	20.25	131	4.5	20.25
18	7	49	56	6	36	94	4.5	20.25	132	4.5	20.25
19	7	49	57	4.5	20.25	95	4.5	20.25	133	4.5	20.25
20	7	49	58	4.5	20.25	96	4.5	20.25	134	4.5	20.25
21	7	49	59	4.5	20.25	97	4.5	20.25	135	4.5	20.25
22	7	49	60	4.5	20.25	98	4.5	20.25	136	4.5	20.25
23	7	49	61	4.5	20.25	99	4.5	20.25	137	4.5	20.25
24	7	49	62	4.5	20.25	100	4.5	20.25	138	4.5	20.25
25	6.5	42.25	63	4.5	20.25	101	4.5	20.25	139	4.5	20.25
26	6.5	42.25	64	4.5	20.25	102	4.5	20.25	140	4.5	20.25
27	6.5	42.25	65	4.5	20.25	103	4.5	20.25	141	4.5	20.25
28	6.5	42.25	66	4.5	20.25	104	4.5	20.25	142	4.5	20.25
29	6.5	42.25	67	4.5	20.25	105	4.5	20.25	143	4.5	20.25
30	6.5	42.25	68	4.5	20.25	106	4.5	20.25	144	4.5	20.25
31	6.5	42.25	69	4.5	20.25	107	4.5	20.25	Total		5833
32	6.5	42.25	70	4.5	20.25	108	4.5	20.25			
33	6.5	42.25	71	4.5	20.25	109	4.5	20.25			
34	6.5	42.25	72	4.5	20.25	110	4.5	20.25			
35	6.5	42.25	73	4.5	20.25	111	4.5	20.25			
36	6.5	42.25	74	4.5	20.25	112	4.5	20.25			
37	6.5	42.25	75	4.5	20.25	113	4.5	20.25			
38	6.5	42.25	76	4.5	20.25	114	4.5	20.25			

Ts = Average wave period of the highest 1/3 of the waves

$$Ts = \overline{T_{1/3}}$$

$$Ts = \frac{\sum_{i=48}^{n} Ti}{N}$$

$$Ts = \frac{392}{48}$$

$$Ts = 8.1667s$$

$$Trms = \sqrt{\sum \frac{Ti^2}{N}}$$

$$Trms = \sqrt{\frac{5833}{144}}$$

$$Trms = 6.3645s$$

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 330 [315 - 345 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Calculation:
Rearrange Ho in receding manner:

No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2	No.	Ho (m)	Ho^2
1	5	25	38	1.5	2.25	75	1	1	112	1	1	149	0.5	0.25
2	4	16	39	1.5	2.25	76	1	1	113	1	1	150	0.5	0.25
3	3	9	40	1.5	2.25	77	1	1	114	1	1	151	0.5	0.25
4	2.5	6.25	41	1.5	2.25	78	1	1	115	1	1	152	0.5	0.25
5	2.5	6.25	42	1.5	2.25	79	1	1	116	1	1	153	0.5	0.25
6	2.5	6.25	43	1.5	2.25	80	1	1	117	1	1	154	0.5	0.25
7	2.5	6.25	44	1.5	2.25	81	1	1	118	1	1	155	0.5	0.25
8	2.5	6.25	45	1.5	2.25	82	1	1	119	1	1	156	0.5	0.25
9	2.5	6.25	46	1.5	2.25	83	1	1	120	1	1	157	0.5	0.25
10	2.5	6.25	47	1.5	2.25	84	1	1	121	1	1	158	0.5	0.25
11	2.5	6.25	48	1.5	2.25	85	1	1	122	1	1	159	0.5	0.25
12	2	4	49	1.5	2.25	86	1	1	123	1	1	160	0.5	0.25
13	2	4	50	1.5	2.25	87	1	1	124	1	1	161	0.5	0.25
14	2	4	51	1.5	2.25	88	1	1	125	1	1	Total		326
15	2	4	52	1.5	2.25	89	1	1	126	1	1			
16	2	4	53	1.5	2.25	90	1	1	127	1	1			
17	2	4	54	1.5	2.25	91	1	1	128	0.5	0.25			
18	2	4	55	1.5	2.25	92	1	1	129	0.5	0.25			
19	2	4	56	1.5	2.25	93	1	1	130	0.5	0.25			
20	2	4	57	1.5	2.25	94	1	1	131	0.5	0.25			
21	2	4	58	1.5	2.25	95	1	1	132	0.5	0.25			
22	2	4	59	1.5	2.25	96	1	1	133	0.5	0.25			
23	2	4	60	1.5	2.25	97	1	1	134	0.5	0.25			
24	2	4	61	1.5	2.25	98	1	1	135	0.5	0.25			
25	1.5	2.25	62	1.5	2.25	99	1	1	136	0.5	0.25			
26	1.5	2.25	63	1.5	2.25	100	1	1	137	0.5	0.25			
27	1.5	2.25	64	1.5	2.25	101	1	1	138	0.5	0.25			
28	1.5	2.25	65	1.5	2.25	102	1	1	139	0.5	0.25			
29	1.5	2.25	66	1.5	2.25	103	1	1	140	0.5	0.25			
30	1.5	2.25	67	1.5	2.25	104	1	1	141	0.5	0.25			
31	1.5	2.25	68	1.5	2.25	105	1	1	142	0.5	0.25			
32	1.5	2.25	69	1.5	2.25	106	1	1	143	0.5	0.25			
33	1.5	2.25	70	1.5	2.25	107	1	1	144	0.5	0.25			
34	1.5	2.25	71	1.5	2.25	108	1	1	145	0.5	0.25			
35	1.5	2.25	72	1.5	2.25	109	1	1	146	0.5	0.25			
36	1.5	2.25	73	1.5	2.25	110	1	1	147	0.5	0.25			
37	1.5	2.25	74	1.5	2.25	111	1	1	148	0.5	0.25			

Hs = Average wave height of the highest 1/3 of the waves

$$Hs = \overline{H_{1/3}}$$

$$Hs = \frac{\sum_{i=54}^{n} Hi}{N}$$

$$Hs = \frac{103}{54}$$

$$Hs = 1.9074\text{m}$$

$$Hrms = \sqrt{\sum \frac{Hi^2}{N}}$$

$$Hrms = \sqrt{\frac{326}{161}}$$

$$Hrms = 1.423\text{m}$$

MARSDEN SQUARE : 2759 2650 2749 2640 2739 2630
CHOSEN DIRECTION : 330 [315 - 345 Degrees]
CHOSEN DIRECTION : JAN FEB MAC APR MAY JUN JUL AUG SEP OCT NOV DEC

Calculation:
Rearrange To in receding manner:

No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2	No.	To (s)	To^2
1	14	196	38	6.5	42.25	75	4.5	20.25	112	4.5	20.25	149	4.5	20.25
2	14	196	39	6.5	42.25	76	4.5	20.25	113	4.5	20.25	150	4.5	20.25
3	14	196	40	6.5	42.25	77	4.5	20.25	114	4.5	20.25	151	4.5	20.25
4	14	196	41	6.5	42.25	78	4.5	20.25	115	4.5	20.25	152	4.5	20.25
5	14	196	42	6.5	42.25	79	4.5	20.25	116	4.5	20.25	153	4.5	20.25
6	12	144	43	6.5	42.25	80	4.5	20.25	117	4.5	20.25	154	4.5	20.25
7	11	121	44	6.5	42.25	81	4.5	20.25	118	4.5	20.25	155	4.5	20.25
8	10.5	110.25	45	6.5	42.25	82	4.5	20.25	119	4.5	20.25	156	4.5	20.25
9	10.5	110.25	46	6.5	42.25	83	4.5	20.25	120	4.5	20.25	157	4.5	20.25
10	10	100	47	6.5	42.25	84	4.5	20.25	121	4.5	20.25	158	4.5	20.25
11	9	81	48	6.5	42.25	85	4.5	20.25	122	4.5	20.25	159	4.5	20.25
12	8.5	72.25	49	6.5	42.25	86	4.5	20.25	123	4.5	20.25	160	4.5	20.25
13	8.5	72.25	50	6.5	42.25	87	4.5	20.25	124	4.5	20.25	161	4.5	20.25
14	8.5	72.25	51	6.5	42.25	88	4.5	20.25	125	4.5	20.25	Total		6220.75
15	8.5	72.25	52	6.5	42.25	89	4.5	20.25	126	4.5	20.25			
16	8.5	72.25	53	6.5	42.25	90	4.5	20.25	127	4.5	20.25			
17	8.5	72.25	54	6.5	42.25	91	4.5	20.25	128	4.5	20.25			
18	8	64	55	6.5	42.25	92	4.5	20.25	129	4.5	20.25			
19	8	64	56	6.5	42.25	93	4.5	20.25	130	4.5	20.25			
20	8	64	57	6	36	94	4.5	20.25	131	4.5	20.25			
21	8	64	58	6	36	95	4.5	20.25	132	4.5	20.25			
22	8	64	59	6	36	96	4.5	20.25	133	4.5	20.25			
23	8	64	60	6	36	97	4.5	20.25	134	4.5	20.25			
24	7	49	61	6	36	98	4.5	20.25	135	4.5	20.25			
25	7	49	62	6	36	99	4.5	20.25	136	4.5	20.25			
26	7	49	63	6	36	100	4.5	20.25	137	4.5	20.25			
27	7	49	64	6	36	101	4.5	20.25	138	4.5	20.25			
28	7	49	65	6	36	102	4.5	20.25	139	4.5	20.25			
29	7	49	66	6	36	103	4.5	20.25	140	4.5	20.25			
30	7	49	67	6	36	104	4.5	20.25	141	4.5	20.25			
31	6.5	42.25	68	6	36	105	4.5	20.25	142	4.5	20.25			
32	6.5	42.25	69	4.5	20.25	106	4.5	20.25	143	4.5	20.25			
33	6.5	42.25	70	4.5	20.25	107	4.5	20.25	144	4.5	20.25			
34	6.5	42.25	71	4.5	20.25	108	4.5	20.25	145	4.5	20.25			
35	6.5	42.25	72	4.5	20.25	109	4.5	20.25	146	4.5	20.25			
36	6.5	42.25	73	4.5	20.25	110	4.5	20.25	147	4.5	20.25			
37	6.5	42.25	74	4.5	20.25	111	4.5	20.25	148	4.5	20.25			

Ts = Average wave period of the highest 1/3 of the waves

$$Ts = \overline{T_{1/3}}$$

$$Ts = \frac{\sum_{i=54}^{n} Ti}{N}$$

$$Ts = \frac{437}{54}$$

$$Ts = 8.0926s$$

$$Trms = \sqrt{\sum \frac{Ti^2}{N}}$$

$$Trms = \sqrt{\frac{6220.75}{161}}$$

$$Trms = 6.2160s$$

Wave Height Direction at 150°

Gumbel Distribution Equation:

$$Y = -\ln\left(\ln\frac{1}{P}\right) = G \qquad A = \frac{1}{\beta} \qquad Y = AX + B$$

$$X = H \qquad B = -\frac{\gamma}{\beta} \qquad P = P(H' \leq H)$$

$$P_x = \frac{N_1 + N_2 + \ldots + N_x}{N_{Total}}$$

λ = Number of events per year

$$\lambda = \frac{N_{Events}}{N_{Year}}$$

Wave Direction = 150 degrees

H	N	P	G
0.5	42	0.2897	-0.2144
1	60	0.7034	1.0448
1.5	32	0.9241	2.5397
2	9	0.9862	4.2767
2.5	2	1.0000	
3			
3.5			
4			
4.5			
5			
Total	145		

From **Figure 4.9**,

Y = 2.9936X - 1.8303

To find β and γ,

$$A = \frac{1}{\beta}$$

$$2.9936 = \frac{1}{\beta}$$

$$\beta = 0.3340$$

$$B = -\frac{\gamma}{\beta}$$

$$-1.8303 = -\frac{\gamma}{0.3340}$$

$$\gamma = 0.6113$$

$$\lambda = \frac{N_{Events}}{N_{Year}}$$

$$\lambda = \frac{145}{33}$$

$$\lambda = 4.3939$$

Wave Height Direction at 180°

Gumbel Distribution Equation:

$$Y = -\ln\left(\ln\frac{1}{P}\right) = G \qquad A = \frac{1}{\beta} \qquad Y = AX + B$$

$$X = H \qquad B = -\frac{\gamma}{\beta} \qquad P = P(H' \le H)$$

λ = Number of events per year

$$\lambda = \frac{N_{\text{Events}}}{N_{\text{Year}}} \qquad P_x = \frac{N_1 + N_2 + \ldots + N_x}{N_{Total}}$$

Wave Direction = 180 degrees

H	N	P	G
0.5	41	0.3361	-0.0866
1	54	0.7787	1.3857
1.5	18	0.9262	2.5687
2	6	0.9754	3.6930
2.5	2	0.9918	4.7999
3	1	1.0000	
3.5			
4			
4.5			
5			
Total	122		

From **Figure 4.10**,

Y = 2.4161X - 1.1519

To find β and γ,

$$A = \frac{1}{\beta}$$

$$2.4161 = \frac{1}{\beta}$$

$$\beta = 0.4139$$

$$B = -\frac{\gamma}{\beta}$$

$$-1.1519 = -\frac{\gamma}{0.4139}$$

$$\gamma = 0.4768$$

$$\lambda = \frac{N_{\text{Events}}}{N_{\text{Year}}}$$

$$\lambda = \frac{122}{30}$$

$$\lambda = 4.0667$$

Wave Height Direction at 210°

Gumbel Distribution Equation:

$$Y = -\ln\left(\ln\frac{1}{P}\right) = G \qquad A = \frac{1}{\beta} \qquad Y = AX + B$$

$$X = H \qquad B = -\frac{\gamma}{\beta} \qquad P = P(H' \leq H)$$

$$P_x = \frac{N_1 + N_2 + \ldots + N_x}{N_{Total}}$$

λ = Number of events per year

$$\lambda = \frac{N_{\text{Events}}}{N_{\text{Year}}}$$

Wave Direction = 210 degrees

H	N	P	G
0.5	65	0.4887	0.3341
1	43	0.8120	1.5692
1.5	14	0.9173	2.4496
2	9	0.9850	4.1896
2.5	1	0.9925	4.8866
3	1	1.0000	
3.5			
4			
4.5			
5			
Total	133		

From **Figure 4.11**,

Y = 2.3451X - 0.8318

To find β and γ,

$$A = \frac{1}{\beta}$$

$$2.3451 = \frac{1}{\beta}$$

$$\beta = 0.4264$$

$$B = -\frac{\gamma}{\beta}$$

$$-0.8318 = -\frac{\gamma}{0.4264}$$

$$\gamma = 0.3547$$

$$\lambda = \frac{N_{\text{Events}}}{N_{\text{Year}}}$$

$$\lambda = \frac{133}{34}$$

$$\lambda = 3.9118$$

Wave Height Direction at 240°

Gumbel Distribution Equation:

$$Y = -\ln\left(\ln\frac{1}{P}\right) = G \qquad A = \frac{1}{\beta}$$

$$X = H \qquad B = -\frac{\gamma}{\beta}$$

λ = Number of events per year

$$\lambda = \frac{\mathrm{N}_{\text{Events}}}{\mathrm{N}_{\text{Year}}}$$

$$Y = AX + B$$

$$P = P(H' \leq H)$$

$$P_x = \frac{N_1 + N_2 + ... + N_x}{N_{Total}}$$

Wave Direction = 240 degrees

H	N	P	G
0.5	46	0.3898	0.0597
1	49	0.8051	1.5287
1.5	11	0.8983	2.2326
2	7	0.9576	3.1397
2.5	3	0.9831	4.0690
3	1	0.9915	4.7664
3.5	1	1.0000	
4			
4.5			
5			
Total	118		

From **Figure 4.12**,

Y = 1.8321X - 0.5734

To find β and γ,

$$A = \frac{1}{\beta}$$

$$1.8321 = \frac{1}{\beta}$$

$$\beta = 0.5458$$

$$B = -\frac{\gamma}{\beta}$$

$$-0.5734 = -\frac{\gamma}{0.5458}$$

$$\gamma = 0.3130$$

$$\lambda = \frac{\mathrm{N}_{\text{Events}}}{\mathrm{N}_{\text{Year}}}$$

$$\lambda = \frac{118}{31}$$

$$\lambda = 3.8065$$

Wave Height Direction at 270°

Gumbel Distribution Equation:

$$Y = -\ln\left(\ln\frac{1}{P}\right) = G \qquad A = \frac{1}{\beta}$$

$$X = H \qquad B = -\frac{\gamma}{\beta}$$

λ = Number of events per year

$$\lambda = \frac{\mathrm{N}_{\text{Events}}}{\mathrm{N}_{\text{Year}}}$$

$$Y = AX + B$$

$$P = P(H' \leq H)$$

$$P_x = \frac{N_1 + N_2 + \ldots + N_x}{N_{Total}}$$

Wave Direction = 270 degrees

H	N	P	G
0.5	28	0.1918	-0.5016
1	74	0.6986	1.0255
1.5	28	0.8904	2.1535
2	12	0.9726	3.5835
2.5	3	0.9932	4.9802
3	0	0.9932	4.9802
3.5	1	1.0000	
4			
4.5			
5			
Total	146		

From **Figure 4.13**,

Y = 2.3259X - 1.3668

To find β and γ,

$$A = \frac{1}{\beta}$$

$$2.3259 = \frac{1}{\beta}$$

$$\beta = 0.4299$$

$$B = -\frac{\gamma}{\beta}$$

$$-1.3668 = -\frac{\gamma}{0.4299}$$

$$\gamma = 0.5876$$

$$\lambda = \frac{\mathrm{N}_{\text{Events}}}{\mathrm{N}_{\text{Year}}}$$

$$\lambda = \frac{146}{34}$$

$$\lambda = 4.2941$$

Wave Height Direction at 300°

Gumbel Distribution Equation:

$$Y = -\ln\left(\ln\frac{1}{P}\right) = G$$

$$A = \frac{1}{\beta}$$

$$Y = AX + B$$

$$X = H$$

$$B = -\frac{\gamma}{\beta}$$

$$P = P(H' \leq H)$$

$$P_x = \frac{N_1 + N_2 + \ldots\ldots + N_x}{N_{Total}}$$

λ = Number of events per year

$$\lambda = \frac{N_{Events}}{N_{Year}}$$

Wave Direction = 300 degrees

H	N	P	G
0.5	25	0.1736	-0.5602
1	35	0.4167	0.1330
1.5	48	0.7500	1.2459
2	25	0.9236	2.5324
2.5	7	0.9722	3.5695
3	0	0.9722	3.5695
3.5	3	0.9931	4.9663
4	0	0.9931	4.9663
4.5	1	1.0000	
5			
Total	144		

From **Figure 4.14**,

Y = 1.6871X - 1.2432

To find β and γ,

$$A = \frac{1}{\beta}$$

$$1.6871 = \frac{1}{\beta}$$

$$\beta = 0.5927$$

$$B = -\frac{\gamma}{\beta}$$

$$-1.2432 = -\frac{\gamma}{0.5927}$$

$$\gamma = 0.7368$$

$$\lambda = \frac{N_{Events}}{N_{Year}}$$

$$\lambda = \frac{144}{32}$$

$$\lambda = 4.5$$

Wave Height Direction at 330°

Gumbel Distribution Equation:

$$Y = -\ln\left(\ln\frac{1}{P}\right) = G \qquad A = \frac{1}{\beta} \qquad Y = AX + B$$

$$X = H \qquad B = -\frac{\gamma}{\beta} \qquad P = P(H' \le H)$$

λ = Number of events per year

$$\lambda = \frac{N_{\text{Events}}}{N_{\text{Year}}} \qquad P_x = \frac{N_1 + N_2 + \ldots + N_x}{N_{Total}}$$

Wave Direction = 330 degrees

H	N	P	G
0.5	34	0.2112	-0.4415
1	53	0.5404	0.4853
1.5	50	0.8509	1.8237
2	13	0.9317	2.6483
2.5	8	0.9814	3.9734
3	1	0.9876	4.3820
3.5	0	0.9876	4.3820
4	1	0.9938	5.0783
4.5	0	0.9938	5.0783
5	1	1.0000	
Total	161		

From **Figure 4.15**,

Y = 1.4236X - 0.5135

To find β and γ,

$$A = \frac{1}{\beta}$$

$$1.4236 = \frac{1}{\beta}$$

$$\beta = 0.7024$$

$$B = -\frac{\gamma}{\beta}$$

$$-0.5135 = -\frac{\gamma}{0.7024}$$

$$\gamma = 0.3607$$

$$\lambda = \frac{N_{\text{Events}}}{N_{\text{Year}}}$$

$$\lambda = \frac{161}{34}$$

$$\lambda = 4.7353$$

Wave Period Direction at 180°

Gumbel Distribution Equation:

$$Y = -\ln\left(\ln\frac{1}{P}\right) = G \qquad A = \frac{1}{\beta} \qquad Y = AX + B$$

λ = Number of events per year

$$B = -\frac{\gamma}{\beta} \qquad P = P(T' \leq T)$$

$$\lambda = \frac{N_{Events}}{N_{Year}} \qquad X = T \qquad P_x = \frac{N_1 + N_2 + \ldots.. + N_x}{N_{Total}}$$

Wave Direction = 180 degrees

Wave Period, T (s)	N	P	G
4.5	89	0.7295	1.1540
6	7	0.7869	1.4285
6.5	12	0.8852	2.1046
7	1	0.8934	2.1833
8	4	0.9262	2.5687
8.5	1	0.9344	2.6909
10	1	0.9426	2.8287
11	1	0.9508	2.9872
12	1	0.9590	3.1737
13	2	0.9754	3.6930
14	3	1.0000	
Total	122		

From **Figure 4.18**,

Y = 0.2698X + 0.1472

To find β and γ,

$$A = \frac{1}{\beta}$$

$$0.2698 = \frac{1}{\beta}$$

$$\beta = 3.7064$$

$$B = -\frac{\gamma}{\beta}$$

$$0.1472 = -\frac{\gamma}{3.7064}$$

$$\gamma = -0.5456$$

$$\lambda = \frac{N_{Events}}{N_{Year}}$$

$$\lambda = \frac{122}{30}$$

$$\lambda = 4.0667$$

Wave Period Direction at 210°

Gumbel Distribution Equation:

$$Y = -\ln\left(\ln\frac{1}{P}\right) = G \qquad A = \frac{1}{\beta} \qquad Y = AX + B$$

λ = Number of events per year

$$B = -\frac{\gamma}{\beta} \qquad P = P(T' \leq T)$$

$$\lambda = \frac{N_{Events}}{N_{Year}} \qquad X = T \qquad P_x = \frac{N_1 + N_2 + ... + N_x}{N_{Total}}$$

Wave Direction = 210 degrees

Wave Period, T (s)	N	P	G
4.5	99	0.7444	1.2200
6	5	0.7820	1.4026
6.5	9	0.8496	1.8142
7	1	0.8571	1.8698
8	2	0.9023	2.2744
8.5	4	0.9173	2.4496
9	2	0.9248	2.5489
10.5	1	0.9248	2.5489
12	1	0.9323	2.6583
13	6	0.9774	3.7804
14	3	1.0000	
Total	133		

From **Figure 4.19**,

Y = 0.2554X + 0.0855

To find β and γ,

$$A = \frac{1}{\beta}$$

$$0.2554 = \frac{1}{\beta}$$

$$\beta = 3.9154$$

$$B = -\frac{\gamma}{\beta}$$

$$0.0855 = -\frac{\gamma}{3.9154}$$

$$\gamma = -0.3348$$

$$\lambda = \frac{N_{Events}}{N_{Year}}$$

$$\lambda = \frac{133}{34}$$

$$\lambda = 3.9118$$

Wave Period Direction at 240°

Gumbel Distribution Equation:

$$Y = -\ln\left(\ln\frac{1}{P}\right) = G \qquad A = \frac{1}{\beta} \qquad Y = AX + B$$

λ = Number of events per year

$$B = -\frac{\gamma}{\beta} \qquad P = P(T' \leq T)$$

$$\lambda = \frac{N_{Events}}{N_{Year}} \qquad X = T \qquad P_x = \frac{N_1 + N_2 + ... + N_x}{N_{Total}}$$

Wave Direction = 240 degrees

Wave Period, T (s)	N	P	G
4.5	88	0.7586	1.2864
6	8	0.8276	1.6647
6.5	7	0.8879	2.1298
7	7	0.9483	2.9354
8	1	0.9741	3.6419
8.5	2	0.9914	4.7493
9	2	1.0000	
10	1	1.0000	
Total	116		

From **Figure 4.20**,

Y = 0.8599X - 3.0701

To find β and γ,

$$A = \frac{1}{\beta}$$

$$0.8599 = \frac{1}{\beta}$$

$$\beta = 1.1629$$

$$B = -\frac{\gamma}{\beta}$$

$$-3.0701 = -\frac{\gamma}{1.1629}$$

$$\gamma = 3.5703$$

$$\lambda = \frac{N_{Events}}{N_{Year}}$$

$$\lambda = \frac{118}{31}$$

$$\lambda = 3.8065$$

Wave Period Direction at 270°

Gumbel Distribution Equation:

$$Y = -\ln\left(\ln\frac{1}{P}\right) = G \qquad A = \frac{1}{\beta} \qquad Y = AX + B$$

λ = Number of events per year

$$B = -\frac{\gamma}{\beta} \qquad P = P(T' \leq T)$$

$$\lambda = \frac{N_{Events}}{N_{Year}} \qquad X = T \qquad P_x = \frac{N_1 + N_2 + ... + N_x}{N_{Total}}$$

Wave Direction = 270 degrees

Wave Period, T (s)	N	P	G
4.5	93	0.6370	0.7963
6	13	0.7260	1.1389
6.5	13	0.8151	1.5873
7	7	0.8630	1.9151
8	3	0.9315	2.6458
8.5	7	0.9315	2.6458
10.5	2	0.9452	2.8761
11	1	0.9521	3.0132
13	3	0.9726	3.5835
14	4	1.0000	
Total	146		

From **Figure 4.21**,

Y = 0.3284X - 0.492

To find β and γ,

$$A = \frac{1}{\beta}$$

$$0.3284 = \frac{1}{\beta}$$

$$\beta = 3.0451$$

$$B = -\frac{\gamma}{\beta}$$

$$-0.4920 = -\frac{\gamma}{3.0451}$$

$$\gamma = 1.4982$$

$$\lambda = \frac{N_{Events}}{N_{Year}}$$

$$\lambda = \frac{146}{34}$$

$$\lambda = 4.2941$$

Wave Period Direction at 300°

Gumbel Distribution Equation:

$$Y = -\ln\left(\ln\frac{1}{P}\right) = G$$

$$A = \frac{1}{\beta}$$

$$Y = AX + B$$

λ = Number of events per year

$$B = -\frac{\gamma}{\beta}$$

$$P = P(T' \leq T)$$

$$\lambda = \frac{N_{Events}}{N_{Year}}$$

$$X = T$$

$$P_x = \frac{N_1 + N_2 + \ldots + N_x}{N_{Total}}$$

Wave Direction = 300 degrees

Wave Period, T (s)	N	P	G
4.5	88	0.6111	0.7083
6	11	0.6875	0.9816
6.5	21	0.8333	1.7020
7	10	0.9028	2.2801
8	3	0.9236	2.5324
8.5	2	0.9375	2.7405
9	1	0.9444	2.8619
10	1	0.9514	2.9991
12.5	3	0.9722	3.5695
13	1	0.9792	3.8607
14	1	0.9861	4.2697
20.5	1	0.9931	4.9663
22.5	1	1.0000	
Total	144		

From **Figure 4.22**,

Y = 0.2704X + 0.0966

To find β and γ,

$$A = \frac{1}{\beta}$$

$$0.2704 = \frac{1}{\beta}$$

$$\beta = 3.6982$$

$$B = -\frac{\gamma}{\beta}$$

$$0.0966 = -\frac{\gamma}{0.36982}$$

$$\gamma = -0.3572$$

$$\lambda = \frac{N_{Events}}{N_{Year}}$$

$$\lambda = \frac{144}{32}$$

$$\lambda = 4.5$$

Wave Period Direction at 330°

Gumbel Distribution Equation:

$$Y = -\ln\left(\ln\frac{1}{P}\right) = G \qquad A = \frac{1}{\beta} \qquad Y = AX + B$$

λ = Number of events per year

$$B = -\frac{\gamma}{\beta} \qquad P = P(T' \le T)$$

$$\lambda = \frac{N_{Events}}{N_{Year}} \qquad X = T \qquad P_x = \frac{N_1 + N_2 + \ldots + N_x}{N_{Total}}$$

Wave Direction = 330 degrees

Wave Period, T (s)	N	P	G
4.5	93	0.5776	0.6000
6	12	0.6522	0.8499
6.5	26	0.8137	1.5789
7	7	0.8571	1.8698
8	6	0.8944	2.1929
8.5	6	0.9317	2.6483
9	1	0.9379	2.7469
10	1	0.9441	2.8556
10.5	2	0.9565	3.1134
11	1	0.9627	3.2707
12	1	0.9689	3.4562
14	5	1.0000	
Total	161		

From **Figure 4.23**,

Y = 0.4042X - 1.1282

To find β and γ,

$$A = \frac{1}{\beta}$$

$$0.4042 = \frac{1}{\beta}$$

$$\beta = 2.4740$$

$$B = -\frac{\gamma}{\beta}$$

$$-1.1282 = -\frac{\gamma}{2.4740}$$

$$\gamma = 2.7912$$

$$\lambda = \frac{N_{Events}}{N_{Year}}$$

$$\lambda = \frac{161}{34}$$

$$\lambda = 4.7353$$

8	Wave Height (Spring low): 0.2143 m (Spring high): 0.3954 m	Wave Height (Neap low): 0.2644 m (Neap high): 0.3748 m
	Current (Spring low): 0.09 m/s, 100° (Spring high): 0.16 m/s, 310°	Current (Neap low): 0.08 m/s, 110° (Neap high): 0.10 m/s, 309°
9	Wave Height (Spring low): 0.1551 m (Spring high): 0.2818 m	Wave Height (Neap low): 0.1812 m (Neap high): 0.2551 m
	Current (Spring low): 0.11 m/s, 120° (Spring high): 0.20 m/s, 300°	Current (Neap low): 0.10 m/s, 110° (Neap high): 0.14 m/s, 278°
10	Wave Height (Spring low): 0.1318 m (Spring high): 0.4001 m	Wave Height (Neap low): 0.1631 m (Neap high): 0.3412 m
	Current (Spring low): 0.24 m/s, 140° (Spring high): 0.24 m/s, 320°	Current (Neap low): 0.16 m/s, 140° (Neap high): 0.16 m/s, 320°

Table 2: Return Period at 5 years

Station	Spring Tide		Neap Tide	
1	Wave Height		Wave Height	
	(Spring low):	0.2101 m	(Neap low):	0.2927 m
	(Spring high):	0.5754 m	(Neap high):	0.5118 m
	Current		Current	
	(Spring low):	0.11 m/s, 133°	(Neap low):	0.10 m/s, 130°
	(Spring high):	0.21 m/s, 293°	(Neap high):	0.15 m/s, 292°
2	Wave Height		Wave Height	
	(Spring low):	0.3153 m	(Neap low):	0.3419 m
	(Spring high):	0.4554 m	(Neap high):	0.4253 m
	Current		Current	
	(Spring low):	0.14 m/s, 150°	(Neap low):	0.13 m/s, 124°
	(Spring high):	0.27 m/s, 290°	(Neap high):	0.18 m/s, 288°
3	Wave Height		Wave Height	
	(Spring low):	0.3162 m	(Neap low):	0.3360 m
	(Spring high):	0.4282 m	(Neap high):	0.4042 m
	Current		Current	
	(Spring low):	0.15 m/s, 150°	(Neap low):	0.16 m/s, 125°
	(Spring high):	0.34 m/s, 299°	(Neap high):	0.23 m/s, 300°
4	Wave Height		Wave Height	
	(Spring low):	0.3643 m	(Neap low):	0.3832 m
	(Spring high):	0.4541 m	(Neap high):	0.4362 m
	Current		Current	
	(Spring low):	0.14 m/s, 150°	(Neap low):	0.15 m/s, 120°
	(Spring high):	0.33 m/s, 300°	(Neap high):	0.23 m/s, 300°
5	Wave Height		Wave Height	
	(Spring low):	0.4140 m	(Neap low):	0.4339 m
	(Spring high):	0.4946 m	(Neap high):	0.4753 m
	Current		Current	
	(Spring low):	0.13 m/s, 150°	(Neap low):	0.15 m/s, 120°
	(Spring high):	0.33 m/s, 300°	(Neap high):	0.23 m/s, 300°
6	Wave Height		Wave Height	
	(Spring low):	0.6322 m	(Neap low):	0.6344 m
	(Spring high):	0.6424 m	(Neap high):	0.6436 m
	Current		Current	
	(Spring low):	0.16 m/s, 175°	(Neap low):	0.14 m/s, 159°
	(Spring high):	0.24 m/s, 320°	(Neap high):	0.16 m/s, 321°
7	Wave Height		Wave Height	
	(Spring low):	0.7806 m	(Neap low):	0.7815 m
	(Spring high):	0.7847 m	(Neap high):	0.7839 m
	Current		Current	
	(Spring low):	0.22 m/s, 159°	(Neap low):	0.18 m/s, 116°
	(Spring high):	0.25 m/s, 330°	(Neap high):	0.22 m/s, 330°

8	Wave Height (Spring low): 0.2724 m (Spring high): 0.0614 m	Wave Height (Neap low): 0.3529 m (Neap high): 0.5534 m
	Current (Spring low): 0.10 m/s, 100° (Spring high): 0.16 m/s, 309°	Current (Neap low): 0.08 m/s, 110° (Neap high): 0.11 m/s, 310°
9	Wave Height (Spring low): 0.2142 m (Spring high): 0.3823 m	Wave Height (Neap low): 0.2528 m (Neap high): 0.3502 m
	Current (Spring low): 0.12 m/s, 114° (Spring high): 0.20 m/s, 296°	Current (Neap low): 0.11 m/s, 115° (Neap high): 0.14 m/s, 280°
10	Wave Height (Spring low): 0.1223 m (Spring high): 0.5641 m	Wave Height (Neap low): 0.2012 m (Neap high): 0.4821 m
	Current (Spring low): 0.26 m/s, 140° (Spring high): 0.24 m/s, 318°	Current (Neap low): 0.18 m/s, 138° (Neap high): 0.16 m/s, 318°

Table 3: Return Period at 10 years

Station	Spring Tide		Neap Tide	
1	Wave Height		Wave Height	
	(Spring low):	0.2232 m	(Neap low):	0.3105 m
	(Spring high):	0.6621 m	(Neap high):	0.5823 m
	Current		Current	
	(Spring low):	0.12 m/s, 130°	(Neap low):	0.11 m/s, 126°
	(Spring high):	0.20 m/s, 294°	(Neap high):	0.14 m/s, 290°
2	Wave Height		Wave Height	
	(Spring low):	0.3835 m	(Neap low):	0.4085 m
	(Spring high):	0.5483 m	(Neap high):	0.5099 m
	Current		Current	
	(Spring low):	0.15 m/s, 149°	(Neap low):	0.14 m/s, 126°
	(Spring high):	0.28 m/s, 286°	(Neap high):	0.20 m/s, 286°
3	Wave Height		Wave Height	
	(Spring low):	0.3837 m	(Neap low):	0.4053 m
	(Spring high):	0.5150 m	(Neap high):	0.4851 m
	Current		Current	
	(Spring low):	0.15 m/s, 148°	(Neap low):	0.17 m/s, 125°
	(Spring high):	0.35 m/s, 298°	(Neap high):	0.25 m/s, 298°
4	Wave Height		Wave Height	
	(Spring low):	0.4440 m	(Neap low):	0.4654 m
	(Spring high):	0.5524 m	(Neap high):	0.5294 m
	Current		Current	
	(Spring low):	0.14 m/s, 149°	(Neap low):	0.15 m/s, 126°
	(Spring high):	0.33 m/s, 298°	(Neap high):	0.23 m/s, 298°
5	Wave Height		Wave Height	
	(Spring low):	0.5021 m	(Neap low):	0.5208 m
	(Spring high):	0.5923 m	(Neap high):	0.5752 m
	Current		Current	
	(Spring low):	0.14 m/s, 149°	(Neap low):	0.16 m/s, 117°
	(Spring high):	0.34 m/s, 298°	(Neap high):	0.24 m/s, 299°
6	Wave Height		Wave Height	
	(Spring low):	0.7885 m	(Neap low):	0.7912 m
	(Spring high):	0.7988 m	(Neap high):	0.7972 m
	Current		Current	
	(Spring low):	0.16 m/s, 172°	(Neap low):	0.14 m/s, 160°
	(Spring high):	0.25 m/s, 321°	(Neap high):	0.16 m/s, 322°
7	Wave Height		Wave Height	
	(Spring low):	0.9051 m	(Neap low):	0.9065 m
	(Spring high):	0.9123 m	(Neap high):	0.9105 m
	Current		Current	
	(Spring low):	0.22 m/s, 160°	(Neap low):	0.18 m/s, 115°
	(Spring high):	0.25 m/s, 332°	(Neap high):	0.22 m/s, 332°

8	Wave Height (Spring low): 0.2824 m (Spring high): 0.7322 m	Wave Height (Neap low): 0.3640 m (Neap high): 0.6414 m
	Current (Spring low): 0.10 m/s, 105° (Spring high): 0.16 m/s, 310°	Current (Neap low): 0.09 m/s, 105° (Neap high): 0.12 m/s, 309°
9	Wave Height (Spring low): 0.2521 m (Spring high): 0.4597 m	Wave Height (Neap low): 0.2987 m (Neap high): 0.4206 m
	Current (Spring low): 0.13 m/s, 115° (Spring high): 0.21 m/s, 298°	Current (Neap low): 0.11 m/s, 103° (Neap high): 0.14 m/s, 275°
10	Wave Height (Spring low): 0.1432 m (Spring high): 0.6547 m	Wave Height (Neap low): 0.2212 m (Neap high): 0.5221 m
	Current (Spring low): 0.26 m/s, 141° (Spring high): 0.22 m/s, 321°	Current (Neap low): 0.18 m/s, 139° (Neap high): 0.15 m/s, 319°

Table 4: Return Period at 20 years

Station	Spring Tide		Neap Tide	
1	Wave Height		Wave Height	
	(Spring low):	0.2315 m	(Neap low):	0.3230 m
	(Spring high):	0.7334 m	(Neap high):	0.6053 m
	Current		Current	
	(Spring low):	0.13 m/s, 115°	(Neap low):	0.11 m/s, 120°
	(Spring high):	0.19 m/s, 298°	(Neap high):	0.15 m/s, 300°
2	Wave Height		Wave Height	
	(Spring low):	0.4200 m	(Neap low):	0.4689 m
	(Spring high):	0.6341 m	(Neap high):	0.5854 m
	Current		Current	
	(Spring low):	0.15 m/s, 140°	(Neap low):	0.145 m/s, 138°
	(Spring high):	0.28 m/s, 286°	(Neap high):	0.21 m/s, 281°
3	Wave Height		Wave Height	
	(Spring low):	0.4439 m	(Neap low):	0.4699 m
	(Spring high):	0.5983 m	(Neap high):	0.5621 m
	Current		Current	
	(Spring low):	0.15 m/s, 126°	(Neap low):	0.17 m/s, 115°
	(Spring high):	0.36 m/s, 292°	(Neap high):	0.26 m/s, 298°
4	Wave Height		Wave Height	
	(Spring low):	0.5153 m	(Neap low):	0.5400 m
	(Spring high):	0.6452 m	(Neap high):	0.6179 m
	Current		Current	
	(Spring low):	0.15 m/s, 132°	(Neap low):	0.17 m/s, 115°
	(Spring high):	0.34 m/s, 298°	(Neap high):	0.25 m/s, 303°
5	Wave Height		Wave Height	
	(Spring low):	0.5852 m	(Neap low):	0.6095 m
	(Spring high):	0.6954 m	(Neap high):	0.6707 m
	Current		Current	
	(Spring low):	0.14 m/s, 132°	(Neap low):	0.16 m/s, 117°
	(Spring high):	0.34 m/s, 298°	(Neap high):	0.24 m/s, 298°
6	Wave Height		Wave Height	
	(Spring low):	0.9332 m	(Neap low):	0.9373 m
	(Spring high):	0.9452 m	(Neap high):	0.9435 m
	Current		Current	
	(Spring low):	0.17 m/s, 172°	(Neap low):	0.15 m/s, 158°
	(Spring high):	0.25 m/s, 321°	(Neap high):	0.17 m/s, 320°
7	Wave Height		Wave Height	
	(Spring low):	1.0335 m	(Neap low):	1.0375 m
	(Spring high):	1.0445 m	(Neap high):	1.0428 m
	Current		Current	
	(Spring low):	0.23 m/s, 150°	(Neap low):	0.19 m/s, 114°
	(Spring high):	0.24 m/s, 332°	(Neap high):	0.23 m/s, 330°

8	Wave Height (Spring low): 0.2807 m (Spring high): 0.7854 m	Wave Height (Neap low): 0.3622 m (Neap high): 0.6621 m
	Current (Spring low): 0.10 m/s, 103° (Spring high): 0.17 m/s, 308°	Current (Neap low): 0.09 m/s, 103° (Neap high): 0.13 m/s, 305°
9	Wave Height (Spring low): 0.2800 m (Spring high): 0.5319 m	Wave Height (Neap low): 0.3406 m (Neap high): 0.4834 m
	Current (Spring low): 0.13 m/s, 114° (Spring high): 0.20 m/s, 290°	Current (Neap low): 0.12 m/s, 108° (Neap high): 0.14 m/s, 269°
10	Wave Height (Spring low): 0.1523 m (Spring high): 0.6641 m	Wave Height (Neap low): 0.2312 m (Neap high): 0.5321 m
	Current (Spring low): 0.27 m/s, 140° (Spring high): 0.22 m/s, 320°	Current (Neap low): 0.19 m/s, 138° (Neap high): 0.14 m/s, 318°

Table 5: Return Period at 50 years

Station	Spring Tide		Neap Tide	
1	Wave Height		Wave Height	
	(Spring low):	0.2361 m	(Neap low):	0.3202 m
	(Spring high):	0.7482 m	(Neap high):	0.6263 m
	Current		Current	
	(Spring low):	0.14 m/s, 115°	(Neap low):	0.12 m/s, 122°
	(Spring high):	0.17 m/s, 298°	(Neap high):	0.15 m/s, 299°
2	Wave Height		Wave Height	
	(Spring low):	0.4621 m	(Neap low):	0.5183 m
	(Spring high):	0.7324 m	(Neap high):	0.6723 m
	Current		Current	
	(Spring low):	0.16 m/s, 139°	(Neap low):	0.15 m/s, 135°
	(Spring high):	0.28 m/s, 288°	(Neap high):	0.22 m/s, 277°
3	Wave Height		Wave Height	
	(Spring low):	0.5139 m	(Neap low):	0.5421 m
	(Spring high):	0.7012 m	(Neap high):	0.6628 m
	Current		Current	
	(Spring low):	0.16 m/s, 125°	(Neap low):	0.18 m/s, 122°
	(Spring high):	0.37 m/s, 296°	(Neap high):	0.27 m/s, 299°
4	Wave Height		Wave Height	
	(Spring low):	0.5964 m	(Neap low):	0.6331 m
	(Spring high):	0.7624 m	(Neap high):	0.7302 m
	Current		Current	
	(Spring low):	0.16 m/s, 126°	(Neap low):	0.17 m/s, 122°
	(Spring high):	0.35 m/s, 299°	(Neap high):	0.26 m/s, 298°
5	Wave Height		Wave Height	
	(Spring low):	0.6832 m	(Neap low):	0.7132 m
	(Spring high):	0.8214 m	(Neap high):	0.7948 m
	Current		Current	
	(Spring low):	0.15 m/s, 128°	(Neap low):	0.17 m/s, 119°
	(Spring high):	0.35 m/s, 298°	(Neap high):	0.26 m/s, 298°
6	Wave Height		Wave Height	
	(Spring low):	1.1202 m	(Neap low):	1.1242 m
	(Spring high):	1.1312 m	(Neap high):	1.1303 m
	Current		Current	
	(Spring low):	0.18 m/s, 171°	(Neap low):	0.15 m/s, 153°
	(Spring high):	0.26 m/s, 321°	(Neap high):	0.17 m/s, 320°
7	Wave Height		Wave Height	
	(Spring low):	1.2194 m	(Neap low):	1.2244 m
	(Spring high):	1.2314 m	(Neap high):	1.2271 m
	Current		Current	
	(Spring low):	0.23 m/s, 156°	(Neap low):	0.20 m/s, 118°
	(Spring high):	0.24 m/s, 331°	(Neap high):	0.23 m/s, 330°

8	Wave Height (Spring low): 0.2847 m (Spring high): 0.8184 m	Wave Height (Neap low): 0.3634 m (Neap high): 0.7132 m
	Current (Spring low): 0.10 m/s, 104° (Spring high): 0.17 m/s, 303°	Current (Neap low): 0.10 m/s, 105° (Neap high): 0.136 m/s, 304°
9	Wave Height (Spring low): 0.3042 m (Spring high): 0.3142 m	Wave Height (Neap low): 0.3735 m (Neap high): 0.5582 m
	Current (Spring low): 0.13 m/s, 115° (Spring high): 0.20 m/s, 281°	Current (Neap low): 0.12 m/s, 110° (Neap high): 0.15 m/s, 266°
10	Wave Height (Spring low): 0.1525 m (Spring high): 0.6737 m	Wave Height (Neap low): 0.2361 m (Neap high): 0.5843 m
	Current (Spring low): 0.27 m/s, 142° (Spring high): 0.22 m/s, 320°	Current (Neap low): 0.19 m/s, 138° (Neap high): 0.13 m/s, 318°

Table 6: Return Period at 100 years

Station	Spring Tide		Neap Tide	
1	Wave Height		Wave Height	
	(Spring low):	0.2407 m	(Neap low):	0.3223 m
	(Spring high):	0.7625 m	(Neap high):	0.6427 m
	Current		Current	
	(Spring low):	0.14 m/s, 115°	(Neap low):	0.12 m/s, 123°
	(Spring high):	0.16 m/s, 298°	(Neap high):	0.15 m/s, 298°
2	Wave Height		Wave Height	
	(Spring low):	0.4924 m	(Neap low):	0.5526 m
	(Spring high):	0.8019 m	(Neap high):	0.7310 m
	Current		Current	
	(Spring low):	0.16 m/s, 138°	(Neap low):	0.16 m/s, 133°
	(Spring high):	0.28 m/s, 290°	(Neap high):	0.23 m/s, 275°
3	Wave Height		Wave Height	
	(Spring low):	0.5399 m	(Neap low):	0.5941 m
	(Spring high):	0.7732 m	(Neap high):	0.7318 m
	Current		Current	
	(Spring low):	0.16 m/s, 125°	(Neap low):	0.18 m/s, 126°
	(Spring high):	0.37 m/s, 298°	(Neap high):	0.28 m/s, 299°
4	Wave Height		Wave Height	
	(Spring low):	0.6539 m	(Neap low):	0.6949 m
	(Spring high):	0.8418 m	(Neap high):	0.8051 m
	Current		Current	
	(Spring low):	0.16 m/s, 126°	(Neap low):	0.17 m/s, 126°
	(Spring high):	0.35 m/s, 299°	(Neap high):	0.26 m/s, 298°
5	Wave Height		Wave Height	
	(Spring low):	0.7452 m	(Neap low):	0.7823 m
	(Spring high):	0.9051 m	(Neap high):	0.8781 m
	Current		Current	
	(Spring low):	0.15 m/s, 126°	(Neap low):	0.18 m/s, 120°
	(Spring high):	0.36 m/s, 298°	(Neap high):	0.27 m/s, 298°
6	Wave Height		Wave Height	
	(Spring low):	1.2449 m	(Neap low):	1.2491 m
	(Spring high):	1.2550 m	(Neap high):	1.2548 m
	Current		Current	
	(Spring low):	0.18 m/s, 170°	(Neap low):	0.15 m/s, 150°
	(Spring high):	0.26 m/s, 321°	(Neap high):	0.18 m/s, 320°
7	Wave Height		Wave Height	
	(Spring low):	1.3421 m	(Neap low):	1.3455 m
	(Spring high):	1.3560 m	(Neap high):	1.3535 m
	Current		Current	
	(Spring low):	0.22 m/s, 160°	(Neap low):	0.20 m/s, 120°
	(Spring high):	0.24 m/s, 330°	(Neap high):	0.23 m/s, 330°

8	Wave Height (Spring low): 0.2826 m (Spring high): 0.8399 m	Wave Height (Neap low): 0.3615 m (Neap high): 0.6993 m
	Current (Spring low): 0.10 m/s, 105° (Spring high): 0.20 m/s, 300°	Current (Neap low): 0.12 m/s, 106° (Neap high): 0.14 m/s, 303°
9	Wave Height (Spring low): 0.3215 m (Spring high): 0.6736 m	Wave Height (Neap low): 0.3905 m (Neap high): 0.6111 m
	Current (Spring low): 0.13 m/s, 115° (Spring high): 0.20 m/s, 275°	Current (Neap low): 0.12 m/s, 110° (Neap high): 0.15 m/s, 264°
10	Wave Height (Spring low): 0.1536 m (Spring high): 0.6839 m	Wave Height (Neap low): 0.2429 m (Neap high): 0.6218 m
	Current (Spring low): 0.28 m/s, 141° (Spring high): 0.20 m/s, 320°	Current (Neap low): 0.19 m/s, 137° (Neap high): 0.13 m/s, 317°